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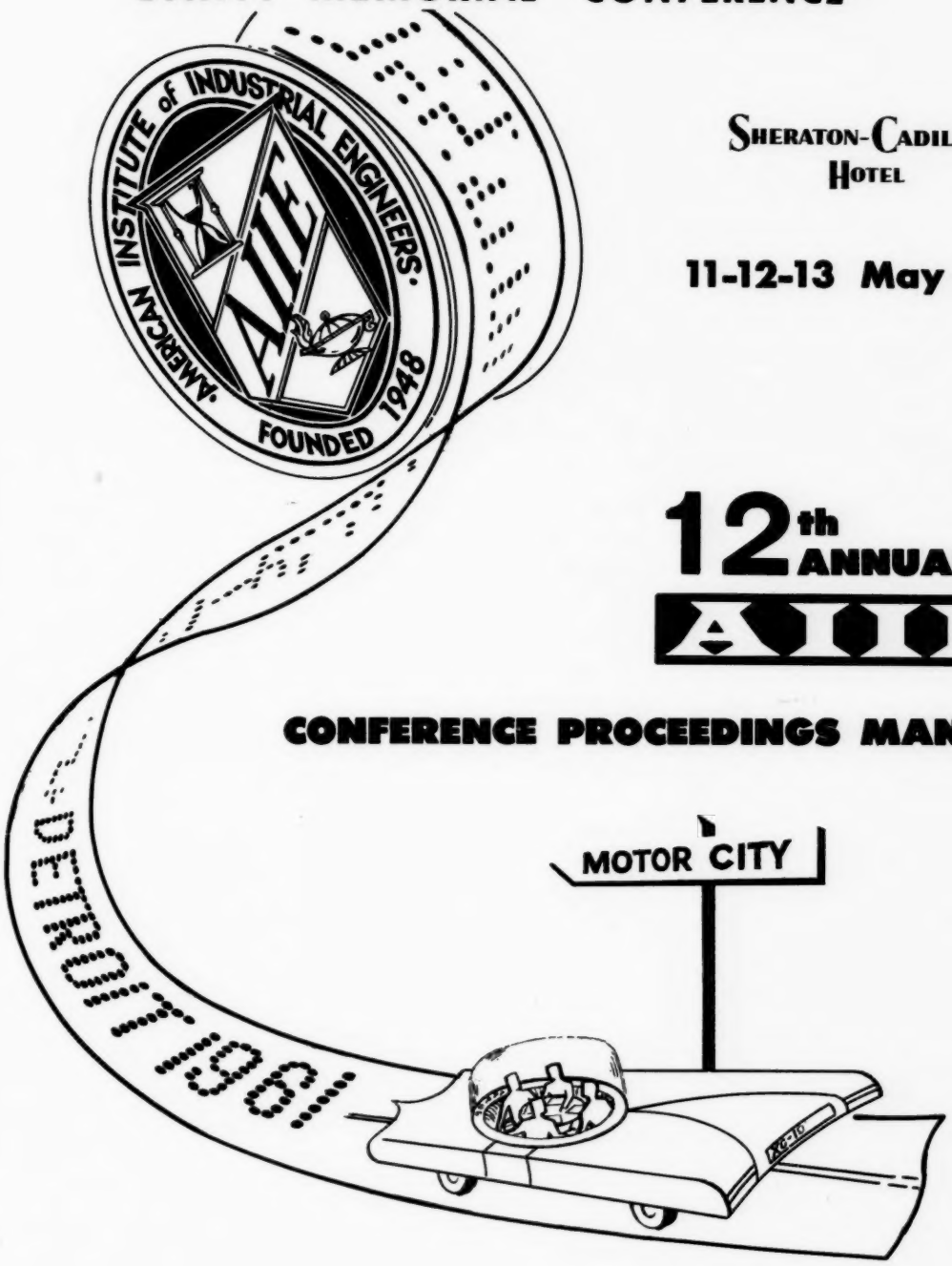
SHERATON-CADILLAC HOTEL

11-12-13 May 1961

12th ANNUAL AIIE

CONFERENCE PROCEEDINGS MANUAL



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FOREWORD

Today, Nationally, as well as Professionally we stand at a new frontier. In order to cope with the problems confronting us in all technical fields, we must prepare ourselves to resolve them by means of the new methods and tools at our disposal. It is to that end that this conference is dedicated.

We are pleased to present herein a complete printing of the speeches and papers presented at the 1961 National Conference of the American Institute of Industrial Engineers. A table of contents is included for your convenience.

Your committee for this conference wishes to express their thanks and appreciation to all those who have presented papers and to all others whose participation has contributed to the success of the conference.

Steven H. Meyers
Chairman,
Proceedings Committee

RESOLUTION

WHEREAS May 20, 1961 will bring the One Hundredth Anniversary of the birth of Henry Laurance Gantt;

WHEREAS Henry Laurence Gantt has been the man who first visualized the scope which Industrial Engineering should occupy;

WHEREAS every Industrial Engineer can bolster his professional career and accomplishments --today and in the years to come--by following Mr. Gantt's down-to-earth practical techniques and philosophy;

WHEREAS the management world has long honored Henry Laurence Gantt's memory as the most outstanding member of our profession--for his insistence on engineering and management work in the service of the community--by attaching his name to its most coveted honor: the Henry Laurence Gantt Gold Medal;

WHEREAS Mr. Gantt's philosophy has been recognized as one of the most respected contributions by the United States to Industrial Engineers and Managers throughout the free world;

THEREFORE BE IT RESOLVED that the American Institute of Industrial Engineers designate the Year 1961 as Henry Laurence Gantt Centennial Year during which special events commemorating this Anniversary will be incorporated in its national, regional and local Conferences and meetings.

Resolution passed by the 1959 A.I.I.E. Convention--Atlanta, Georgia

HENRY LAURENCE GANTT
1861-1919

Henry Laurence Gantt was born May 20, 1861 in Calvert County, Maryland. He was graduated from Johns Hopkins University with a Bachelor of Arts degree at nineteen. Following his B. A. degree, he taught for three years at the McDonough School in Baltimore County which he had attended as a boy, and in 1884, Stevens Institute of Technology conferred the degree of Mechanical Engineering.

Mr. Gantt began his industrial work at Midvale and Bethlehem Steel Companies in association with Frederick W. Taylor. This early union lasted for a short time as Mr. Gantt felt that the Taylor approach was too restrictive, due to its mechanistic ideology. Henry Laurence Gantt believed there was far more to the industrial complex and went on to develop an industrial concept that visualized industrial problems as national problems, with the human element being of prime importance. He placed strong emphasis upon properly trained management. Trained workers, according to Mr. Gantt, would not be sufficient if management lacked proper direction. He believed that business must produce service first, with rewards (profits) the by-product, because "reward according to service rendered is the only foundation on which our industrial and business system can permanently stand."

These principles were radical departures from the philosophy of his day and it becomes apparent to the student of Mr. Gantt's teachings that modern devices do not always correct the situations which he encountered, but merely hide them from the untrained eye.

Mr. Gantt is well remembered for initiating the concept of a task and bonus system, which theorized that rewarding the worker for a good job would mean more in the long run than penalizing him for a poor job. During his work with the Ordnance Department at the time of the first World War, the Gantt Chart technique was developed. It is interesting to note that the techniques introduced by Mr. Gantt were the first means of answering the ever-important industrial questions: Machine utilization (idleness chart), production control (is the machine producing what is needed) and thirdly, machine performance (operator efficiency only after questions one and two had been answered).

Professor David B. Porter of New York University, a former associate of Mr. Gantt, in a talk before the A. S. M. E. on November 30, 1961 described the Gantt Chart's principles as follows: "Mr. Gantt recognized that these charts were more than tools to aid in production planning and control. They are, in reality, effective measures of performance of those at all levels from workman to manager. The record is clear and the responsibilities for either good or poor performances are accurately placed. This is truly a democratizing performance force which causes control to gravitate from weak to strong hands, or as he (Gantt) put it "to those who know what to do and how to do it." This reflects the philosophy of Gantt, who was impatient with any system which covered up the shortcomings of management and caused frustration and ill will within the organization.

In commemorating this hundredth birthday, it is not the cures that Mr. Gantt sought for any particular industry that we should recall now or in the future, but rather the basic principles and philosophies that Henry Laurence Gantt expounded which are not restricted to technological know-how, but are basic to the success and continuing growth of American industry.

Laurence Gantt Taber
Chairman, A.I.I.E. Gantt Centennial Memorial

PURPOSES OF THE AIIE

The AIIE is dedicated to the following purposes:

To maintain the practice of Industrial Engineering on a professional status

To foster a high degree of integrity among the members of the industrial engineering profession

To encourage and assist education among members of the profession

To promote the interchange of ideas and information among members of the profession

To serve in the public interest by identification of men qualified to practice as Industrial Engineers

To promote professional registration of Industrial Engineers.

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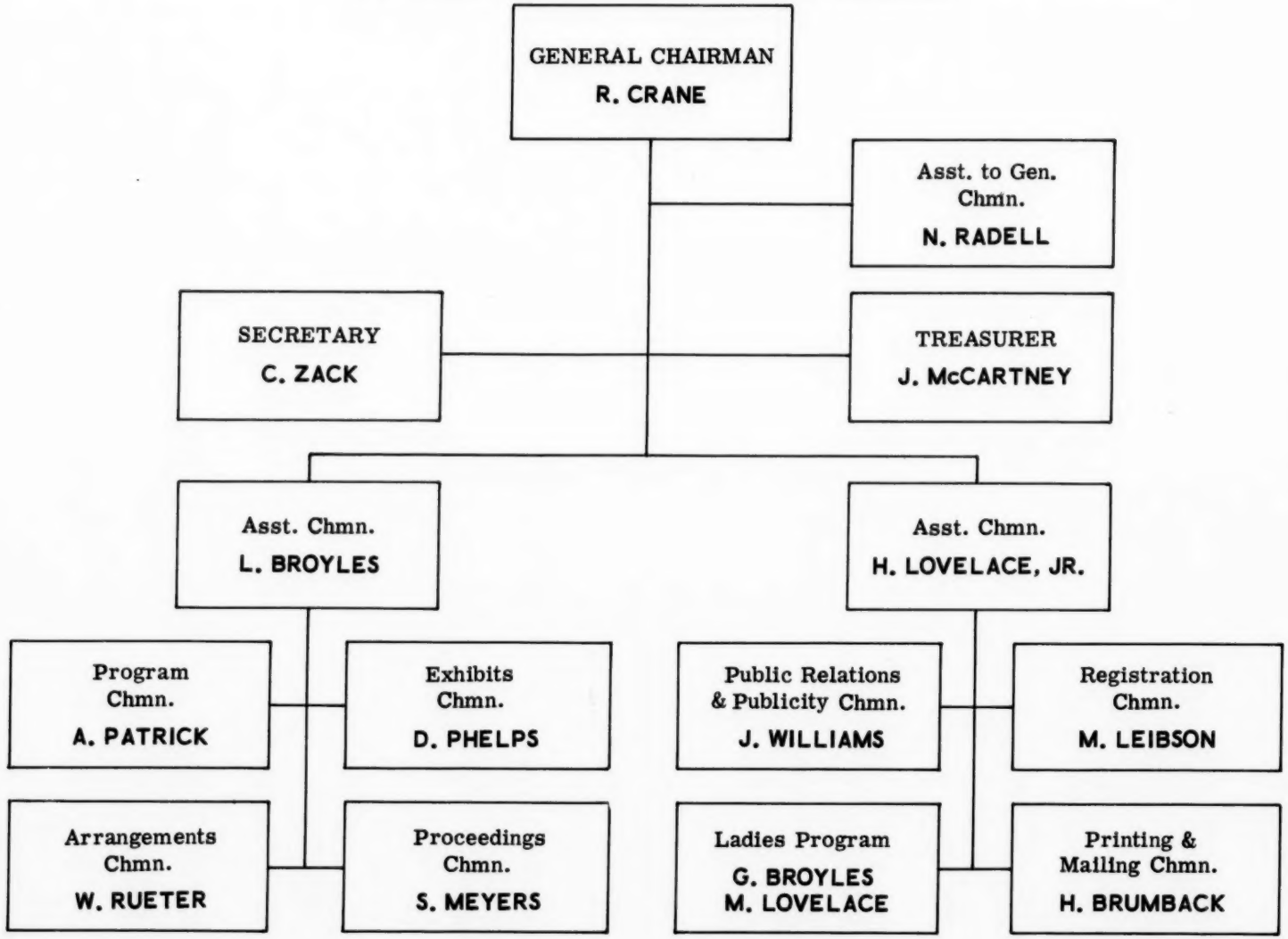

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MATHEMATICAL PROGRAMMING FOR INDUSTRIAL ENGINEERS

by NYLES V. REINFELD
Managing Director
NATIONAL INSTITUTE OF MANAGEMENT, INC.
CLEVELAND, OHIO

Mr. Reinfeld was graduated from Akron University... this was preceded by serving his apprenticeship in several Akron machine shops, and interrupted by wartime duty in the Navy . . . he later attended the University of Michigan acquiring his Master's Degree... he was appointed staff member of the Systems Department at Willow Run . . . business and simulation problems and hi-speed computers, such as the SEAC in Washington, D. C., were next . . . at the Burroughs Corporation he worked on field studies gathering data useful in establishing design of new computers . . . employed by a Pittsburgh consulting firm on an assignment at SKF, he made what is recognized as the first industrial application and installation of Mathematical Programming . . . his experience in this field extended itself to programming Production Control, Inventory Management, Shipping and Allocation, Down Time and Set Up, Salary Evaluation and Purchasing... in 1954 he formed his own training and consulting firm... this was incorporated in 1956 under the name of National Institute of Management and today is one of the largest training firms in the country . . . Mr. Reinfeld has had published a number of articles in leading industrial and technical journals . . . his book on Mathematical Programming (with Wm. R. Vogel) was published in 1958 . . . a new book on Production Control was released by Prentice-Hall in May, 1959 . . . he is a member of numerous technical societies . . . for the past three years he has acted as a private consultant to the United States Government.

MATHEMATICAL PROGRAMMING FOR INDUSTRIAL ENGINEERS

By NYLES V. REINFELD

Managing Director, National Institute of Management, Incorporated

WHAT IS LINEAR PROGRAMMING?

LINEAR Programming is a method for solving mathematically a large number of choices of action and selecting the best answer. The problem when using Linear Programming, as with any problem, is in the formulation. Once the problem has been stated in mathematical terms, the solution can be derived in a very straight-forward manner. In fact, solving the large systems of equations involved in the procedure is currently being done at regular intervals, in several installations, solely by clerical help. In this manner, the more important company personnel are freed from much of their routine so as to devote more time to problems demanding sound judgment.

Once the problem has been properly set up, there are a number of different ways in which the solution can be derived. The procedure used will depend largely upon the complexity of the problem and the urgency for getting an answer.

The more commonly known procedures are three: the Simplex Method, the Transportation (or Distribution) Method, and "Quick and Dirty" Methods.

The Simplex Method of matrix optimization is used for solving complex problems. This method is the one with most general application, and any Linear Programming problem can be solved by means of it. An illustration of this method will appear later in the text.

The Transportation or Distribution Method offers greater facility and speed in solution but is restricted to problems where the efficiency of the alternate choices is the same. Examples of this type include transportation problems, such as confront the railroads where the objective is to supply railroad cars to various customers at a minimum of shipping cost. It may be cheaper, for example, to supply Youngstown with cars located at Pittsburgh and ship cars into Pittsburgh from New York, than to ship the cars directly from New York to Youngstown. The final shipping pattern is determined by the interplay of the unit car shipping costs and the various terminals and customer requirements.

The use of Linear Programming will enable you to allocate these shipments at a minimum cost. And you can do this because Linear Programming considers all factors relative to the solution as a whole, whereas standard procedures treat each factor as a separate problem. Linear Programming is, in a sense, a method for growing in size. Through its use, you can literally get up on top of the problem and look down on the whole network. In actual practice, the schedule clerk solves the whole problem at once, rather than piecemeal. Another advantage of Linear Programming is that you can prove when you have arrived at the best answer; you know that there is no need to look further.

The number of steps employed are always much fewer than would be required if every possibility were to be evaluated separately. In fact, the number of steps required to obtain the best solution is always finite, even if there is an infinite number of alternate choices!

In the case of scheduling on machinery or equipment, it is frequently necessary to get an answer quickly, such as when breakdowns occur. In these cases, it is usually better to solve the problem by Quick and Dirty Methods. In essence, quick and dirty solutions still employ all of the principles of the other solutions. The formulation of the problem is the same as before. The organization, the data needed, and

the patterns of solution are the same as before. The basic difference is that a planned procedure for selective inspection of data is employed, based on the particular peculiarity or special property of the individual situation. This latter point is emphasized because it is not always obvious which types of problems will lend themselves to this or that particular approach. Solutions of this nature will seldom give the best possible answer, but will normally come close enough so as to make the use of high speed computers impractical. It is worth noting that, in those cases where these methods have been employed, the results were far better than had been obtained previously by use of more conventional techniques.

If the solutions must be precise and time is important, then large scale digital computers can be employed. Several of the present computers available for outside use have been programmed for solving Linear Programming problems.

WHAT IS OPERATIONS RESEARCH?

By Annesta R. Gardner

The term is familiar. But what does it really mean? What should executives know about it? Here are answers from the experts.

Judging from the number of talks and seminars on Operations Research scheduled for the coming year, this is a hot topic indeed for the industrial executive. Few management meetings seem complete without a paper on OR these days.

But when it comes to defining the term, or telling how and where the technique should be used, it's a different story.

This is all the more surprising because there is little disagreement as to the origin of the term. It received its first major use during World War II to describe a group of methods, basically statistical in nature, used to study such military operations as strategic bombing, with a view to improving their efficiency.

As Philip M. Morse and George E. Kimball put it in their book on *Methods of Operations Research,* one of the first major publications on the subject:

Operations Research "first developed as a recognized activity in response to the military needs of World War II where it was sometimes known as operations analysis or evaluation. . .

"However . . . the techniques and approach of Operations Research can be of help in arriving at executive decisions concerning operations in any field, industrial and governmental as well as military. . . ."

Because of the latter claim, and because *Operations Research* is a term that is increasingly used in management discussions, Dun's Review and Modern Industry has asked some of those who are most familiar with the term—OR consultants and the heads of OR departments in industry—to give their definitions of the term, and to tell who should use OR methods, and where they should be used. The replies to the survey are summarized at the conclusion of this article.

The definitions (left) are self-explanatory, but the question of "most successful" and "least successful" applications deserves closer attention. The box at the right lists only industrial uses. However, a number of those who responded still feel that Operations Research scores its most notable successes in the military field—in the study of military tactics and strategy, weapons systems, fire control problems, mine detection, mobile gun design, and the like.

As one respondent put it, "these are nearer-term problems and have more specifically definable objectives" than have many industrial applications.

Naturally, most of those who incline to this view are the ones who first approached Operations Research from the military side. These individuals also tend to think of OR as a new entity; while those who approach OR from the industry side, and particularly those who have long used statistical techniques on industry problems, tend to feel that Operations Research

is a new name, and perhaps a new package, for a familiar group of methods.

As Nyles V. Reinfeld of Executive Services, Inc. puts it: "The best definition of Operations Research would seem to be in terms of the tools or techniques used... and many of these techniques—mathematical programming, inventory management, game theory, and the like—predate Operations Research by many years." If, he says, the men working with inventory mathematics were not doing Operations Research, "then Operations Research would seem to result from the collective employment and knowledge of a body of these techniques."

Speaking to the last annual meeting of the American Society of Mechanical Engineers, Professor Andrew Schultz, Jr. of Cornell University said the methodology of Operations Research, as understood by the engineer in industry, "would involve the familiar steps of problem definition; definition of terms and measures; determination of facts; construction of the hypothesis or explanation by empirical, logical or intuitive means; and final testing of conclusions.

"This procedure in itself should not seem new to the engineer whose training involves the fundamentals of physical science," Schultz continues, "although some of the newer techniques may be unfamiliar . . . and . . . the application of the method to the area of operations may seem novel."

Though there are disagreements as to definitions and applications, perhaps the greatest spread of opinion relates to the place of Operations Research in the management scheme. Asked, "When an Operations Research Department is set up within a company, at what level should it report?" respondents covered the organizational front with their answers.

Several named specific job titles, "Executive Vice-President," "General Manager," and so on.

Others believe the Operations Research chief should report to "the executive with overall responsibility for the operation being studied."

Others feel that he should report at a level *above* that of the man responsible for the job being studied—not to the responsible executive himself.

One respondent said the OR chief should report at the highest level at which "there is understanding and support for the work, and a chance of frequent, face-to-face contact."

Should Operations Research be centralized in a single department? "Yes, indeed," said several of its proponents. "Decidedly not," said others.

The first group feels that setting the Operations Research group on its own—perhaps as a management consulting section—enables it to be more objective and to give more complete service.

The second group feels that creating Operations Research cadres within the departments they are to serve makes for closer liaison and better understanding of the specific problems to be solved.

Most likely, each one is right—for his particular needs.

As a matter of fact, the best way to approach the whole Operations Research question is on the basis of specific needs, and with a good deal of caution.

As Reinfeld points out, there are real dangers in going overboard on this "new" idea. In so far as Operations Research becomes a management fad, its adoption may be akin to buying a machine when there is no clear idea as to how it will be used. Far better to approach the subject slowly and then set up a department and train one's own men in the techniques when one is sure of the job to be done.

A good way to start is with the papers delivered during the past three or four years at meetings of such organizations as the American Management Association, the American Society of Mechanical Engineers, the Society of Automotive Engineers, and the Industrial Engineering Institute of the University of California. Several other universities, and such Government organizations as the Office of Naval Research have also held seminars on Operations Research within the past three years.

The National Research Council has several brochures on Operations Research, prepared by its Advisory Committee; and the Council for Technological Advancement has prepared a good brief review of the subject.

Last, but by no means least, is the three-year-old Operations Research Society of America which holds regular meetings at which a good many of the experts in the field may be found.

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HERE IS HOW IT IS DEFINED . . .

To find out what a technical term means, ask the men who use it. That's what DR & MI did with *Operations Research,* by means of a survey, directed to OR staff members in manufacturing firms and industrial consultants in the operations research field. The quotations below and the comments in the adjacent column represent their replies.

PHILIP M. MORSE, *Massachusetts Institute of Technology*

Operations Research is the application of the quantitative, theoretical, and experimental techniques of physical science to a new subject, operations. An operation is the pattern of activity of a group of men and machines doing an assigned, repetitive task.

EDWARD C. VARNUM, *Barber-Colman Company*

Operations Research is the study and solution of problems related to the conduct of industrial or military enterprises, with emphasis upon the techniques and attitudes fostered by the training of its practitioners in pure science.

HORACE C. LEVINSON, *Industrial Consultant*

Operations Research is an application of the method and spirit of scientific research to problems that arise in the general areas of administration and organized activities. Its general purpose is to discover the most rational bases for action decisions.

JOHN E. KUSIK. VICE-PRESIDENT, *Chesapeake and Ohio Railway Company*

Operations Research may be defined as analysis of operations for decision-making purposes and for designing efficient operating systems. The only element of newness in Operations Research is a systematic search for opportunities for the application of scientific techniques developed in the various fields of science. Its greatest contribution to business lies in the emphasis on viewing problems from a company-wide perspective.

CARL E. NOBLE, *Kimberly-Clark Corporation*

Operations Research involves the application of scientific methods to optimize the over-all returns of an organization.

. . .AND HOW IT IS USED

Operations Research seems to have been applied to almost every industrial process and system during the past ten years, with varying degrees of success. Many OR users think it is still too early for final decisions on specific applications, and point out that the way OR is used has much to do with its success. Nonetheless, here are applications which, users say, are:

Most likely to succeed

Production scheduling and telephone congestion
Machinery replacement theory
Investment management
Production and inventory control
Economic controls of manufacture
Machine allocation
Inventory management
Market forecasting

Less certain of success

Development of personnel functions
Organizational problems
Market research
Determining possible uses for new technical developments
Cost control
Long range inventory problems
Development of integrated data processing systems in the accounting function
Production scheduling
Analysis of inventory policy
Management decision problems
Any problem which does not involve a quantitative answer
Salary evaluation

On the middle ground (neither "most successful" nor "least successful"—but worth a try)

Distribution audits
Capital facilities planning
Electrical substation operations
Determining optimum size for mixing tanks
Determining number of men needed for maintenance operation.
Plant and warehouse location studies
Control of productivity rates
Library operation
Advertising effectiveness
Service performance
Analysis of business operations
Allocation of marketing effort

SCHEDULING: MATH SYSTEM PAYS OFF

By T. M. Rohan

**Firms save money, boost output with mathematical programming . . .
Can schedule production for top output, lowest cost or best profits. . .
Will save on paperwork . . . Offer training program**

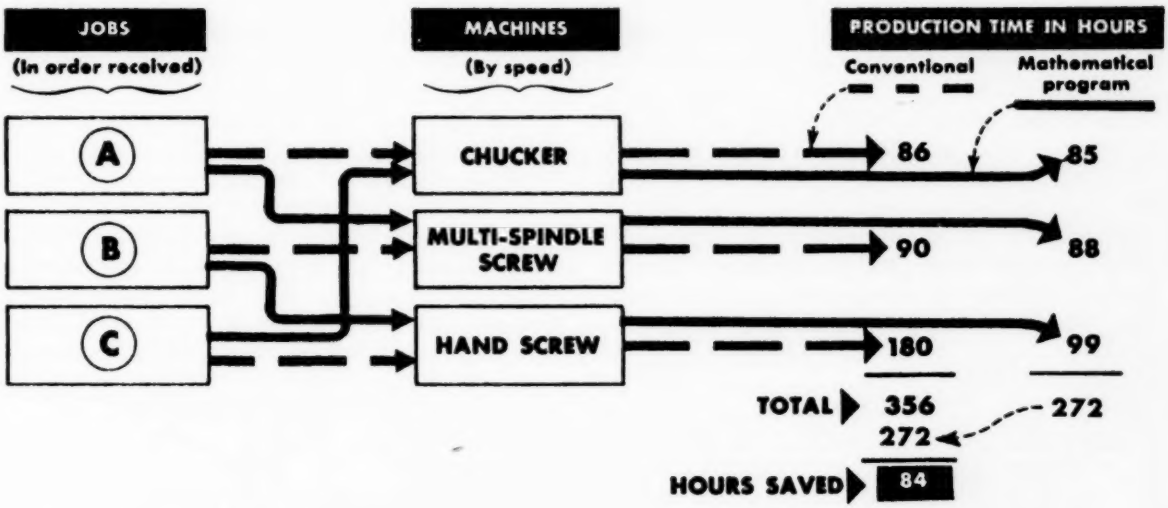
A teamwork proposition – using all the horses rather than just the fastest—is saving thousands of dollars today through mathematical programming. It's a Twentieth Century version of the old mathematician's law of the ratio of advantages.

Mueller Brass Co., Port Huron, Michigan, with 100-150 machines, has shown actual production savings of $100,000 in a year on one operation with the system. A tube mill study there showed profits could be increased 35 per cent by following the mathematical programming setup.

Production increases of up to 20 per cent were accomplished in a year using the system at SKF Industries with 120 automatic screw machines. At another firm with 25 automatics, the system was set up by remote control and is saving about $20,000 annually. H. J. Heinz Company is saving "several thousand dollars" semi-annually in freight by using the principles.

The system has also resulted in major savings through subcontracting, improved inventory control and justification for new equipment.

At present there are an increasing number of firms using mathematical programming and several colleges and consulting firms are actively promoting the work. (See THE IRON AGE, February 18, 1954, page 76). At least one, Executive Services of Cleveland, offers



Simplified application of Mathematical programming for three machines shows 84 hours saved from original 356 necessary. In conventional scheduling Jobs A, B and C are received in that order and scheduled on machines in order of speed, i.e. the chucker, multispindle screw and hand screw. In Mathematical Programming all orders are held in Scheduling until shop is ready. Biggest order (C) although last received is assigned to fastest machine where it is turned out in 85 hours rather than 180. This offsets longer time on smaller orders and slower machines with net gain of 84 hours. In Mathematical Programming the advantage shifts with each product. A larger number of machines also complicates the technique.

training programs in the application of these techniques as well as field installations.

Pressing need of production in World War II forced mathematicians from their classrooms into machine shops resulting in the Operations Evaluation Group, a counterpart to England's Operations Research Group. Their work—which was a basis for War Production Board scheduling by plants—has been reduced to practical terms of what items to schedule in what order on what machine for (1) highest output, (2) lowest cost, (3) highest profit or (4) a variety of other objectives.

Reduced to its simplest terms, it means that in shooting for the highest output, for example, the fastest machine is not always immediately loaded to the hilt and slough-off put on slower machines. Rather, all machines are given a speed rating *For Each Item Produced.*

When emphasis is on keeping costs down, different ratings, previously worked out, are used. Other variations are used for highest profit. System has even been used to streamline office paperwork.

Plant scheduling departments normally schedule orders as received to the limit of the fastest machine. Additional orders are put on the other machines. Work of scheduling is thus expedited and the schedulers desk is always current.

In mathematical programming, each order as received is given a preference rating for three or more machines. These are held at the scheduler's desk until the week's work is to be laid out. When actual scheduling begins, wherever normally slower machines have a speed advantage on a particular job, it is assigned to them.

SOLUTIONS ARE RAPID

Mechanics of the system are readily taught ordinary clerical workers and a schedule for 100 machines can be solved in 2 to 3 hours.

By this same method, students of mathematical programming, after a day's instruction at a recent Executive Services training program, were able to shave production time in a class problem taken from actual schedule from 10,300 hours to 8,300 hours. This amounts to a time reduction of 19 per cent or time for 24 per cent additional output.

Mechanics of setting up such a system are relatively simple under qualified supervision at the start. The methods normally used are approximations and do not necessarily give exactly the best answer. Large scale computers are needed for more precise answers. Approximations, however, are generally sufficient. And with practice, refinements are made which bring the solution very close to the best theoretical answer and far better than by conventional methods.

System is well adapted to independent shops having 100 to 150 machines or in similar size departments of larger firms. It can be set up for this size shop for an average cost of about $2200 representing 4 weeks installation time. If plants elect to send representatives to the 3-week seminars in Cleveland costing $290, they return and instruct company personnel. Executive Services Consultants point out that cost of installation by this method is generally less since students can apply principles to operations they already know.

In a recent highly complicated blending firm scheduling program, the plant representative was able to set up the system with only a week's consultation after taking the course. For an outside consultant at least 6 weeks work at the firm would have been necessary.

Reprinted by special permission, The Iron Age, from Issue of May, 1955.

PRODUCTION CONTROL CUTS SCHEDULE

By Ernest Schleusener and M. W. Maddox

On-time delivery and lowest cost are the top gains in this Mueller program. Success secret: fact-filled reports plus a new twist in linear programming.

Tight control of production has cut excess production hours from 17.5% to 1.2% at Mueller

Brass (see chart at right). That's a 93% reduction. It represents tremendous savings in hours—and in dollars.

Production control is essential in fulfilling the three functions of the manufacturing division: to deliver product or service at lowest cost, with highest quality, at the right time. Primary job of planning is to get the product out at the right time. But, if planning does its job right, it can also help produce at lowest cost.

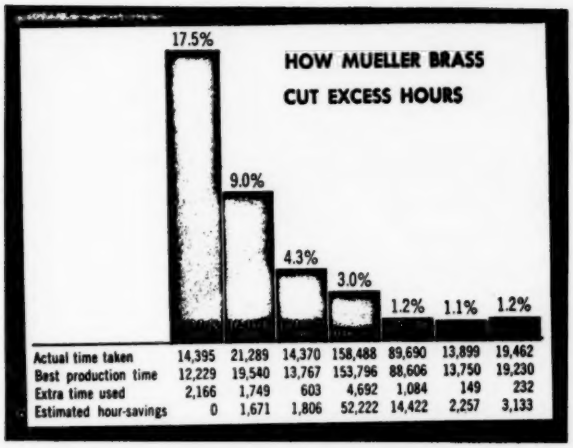
Our program saves money because it holds to four principles:

. . . *Better schedules* that are more realistic mean better use of men and machines, higher efficiency.

. . . *Set-up costs* can be cut by scheduling like parts to run together.

. . . *In-process inventory* can be minimized by scheduling work that will flow evenly through the shop.

. . . *Orders of economical lot size* cut the cost of the product.



Actual time taken	14,395	21,289	14,370	158,488	89,690	13,899	19,462
Best production time	12,229	19,540	13,767	153,796	88,606	13,750	19,230
Extra time used	2,166	1,749	603	4,692	1,084	149	232
Estimated hour-savings	0	1,671	1,806	52,222	14,422	2,257	3,133

Costs drop sharply as excess hours are cut from 17.5% to 1.2%. Reason: intelligent scheduling that sends various jobs to the machines that can do them best.

KEYS TO PROGRAM

Look again at the bars and figures in the chart. They are taken from a periodic report that shows, in this instance, that we have slashed excess hours from 17.5% to 1.2% and increased our estimated savings to 3133 hours in a single month. A footnote on this particular report calls attention to a slight increase in excess hours—from 1.1% in September 1955 to 1.2% in October—then explains the increase ("overloaded condition on the Kingsbury machine classes and the overload on certain automatic screw machines"). This is a hard-hitting, factual report. In these respects, it's like other reports (described below) that go to our executives and supervisors. They are the keys to our production-control program.

Production control must gather basic facts before it can schedule production, predict delivery. Most facts are included in the reports illustrated on these and the next two pages. Other facts needed: time to finish a job, type of equipment jobs are run on, tools to be used.

Departmental load—First, amount of work ahead of all departments should be accumulated. This calls for a simple report (top, opposite page) showing department involved and units to be used as a measure. Units need not be the same for every department—could be hours of work, pounds, pieces, even shifts. Next, it's necessary to know load ahead of each department on a specified date. Backlog will be expressed in number of units ahead on a specified date.

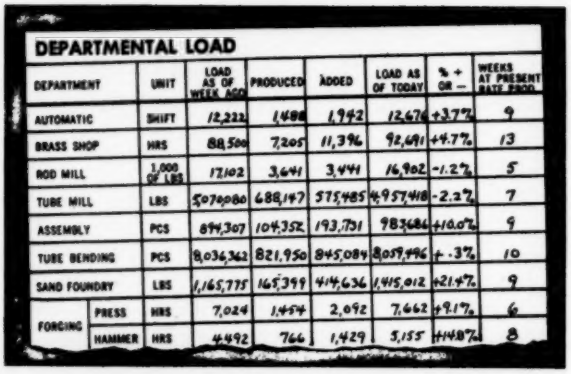
LOSSES

Next, amount of work produced in the previous period, using the same units as a basis of computation, should be shown. Then amount of new work load added in that period.

The simple sum of the work added during the period to the load at the beginning of the period, minus the amount produced during the period, gives the new load as of the current date. The percentage of increase or decrease in load can now be calculated and weeks of work at present production rate can be shown.

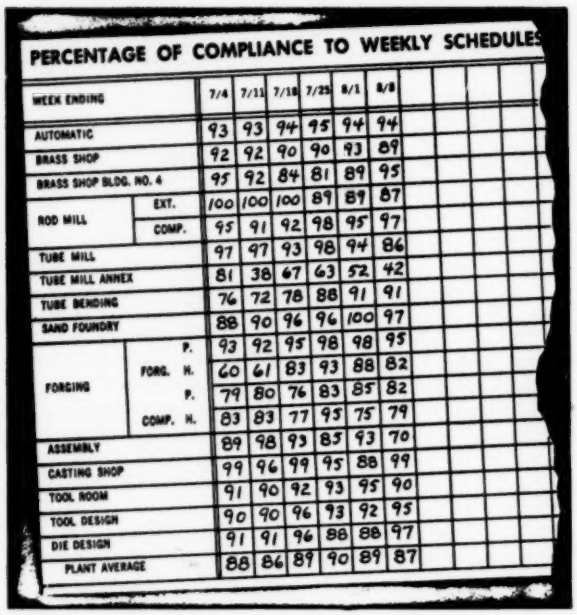
This report is a valuable instrument for many uses. First, it gives production departments an idea of how much work is ahead of them. They can tell whether the load is increasing or decreasing. They can see at a glance whether they are producing more or less than the amount of work that is being added to their department during the period.

We circulate our load report to all branches



DEPARTMENTAL LOAD

DEPARTMENT		UNIT	LOAD AS OF WEEK AGO	PRODUCED	ADDED	LOAD AS OF TODAY	% + OR −	WEEKS AT PRESENT RATE PROD.
AUTOMATIC		SHIFT	12,222	1,488	1,942	12,676	+3.7%	9
BRASS SHOP		HRS	88,500	7,205	11,396	92,691	+4.7%	13
ROD MILL		1,000 OF LBS	17,102	3,641	3,441	16,902	-1.2%	5
TUBE MILL		LBS	5,070,080	688,147	575,485	4,957,418	-2.2%	7
ASSEMBLY		PCS	894,307	104,352	193,731	983,686	+10.0%	9
TUBE BENDING		PCS	8,036,362	821,950	845,084	8,059,496	+ .3%	10
SAND FOUNDRY		LBS	1,165,775	165,399	414,636	1,415,012	+21.4%	9
FORGING	PRESS	HRS	7,024	1,454	2,092	7,662	+9.1%	6
	HAMMER	HRS	4,492	766	1,429	5,155	+14.8%	8



PERCENTAGE OF COMPLIANCE TO WEEKLY SCHEDULES

WEEK ENDING		7/4	7/11	7/18	7/25	8/1	8/8					
AUTOMATIC		93	93	94	95	94	94					
BRASS SHOP		92	92	90	90	93	89					
BRASS SHOP BLDG. NO. 4		95	92	84	81	89	95					
ROD MILL	EXT.	100	100	100	89	89	87					
	COMP.	95	91	92	98	95	97					
TUBE MILL		97	97	93	98	94	86					
TUBE MILL ANNEX		81	38	67	63	52	42					
TUBE BENDING		76	72	78	88	91	91					
SAND FOUNDRY		88	90	96	96	100	97					
FORGING	P.	93	92	95	98	98	95					
	FORG. H.	60	61	83	93	88	82					
	P.	79	80	76	83	85	82					
	COMP. H.	83	83	77	95	75	79					
ASSEMBLY		89	98	93	85	93	70					
CASTING SHOP		99	96	99	95	88	99					
TOOL ROOM		91	90	92	93	95	90					
TOOL DESIGN		90	90	96	93	92	95					
DIE DESIGN		91	91	96	98	88	97					
PLANT AVERAGE		88	86	89	90	89	87					

Facts Pop from these two reports. Load report (top) tells department how much work it has done, how much it has to do, how long it'll stay busy filling orders. Compliance report measures performance against scheduled production.

of management, including the sales department. Trends noted in the report are used to determine when shifts or workers should be added or taken off (in each department) to keep time needed to deliver a product at a proper level.

Our general policy is to operate 48 hours a week for four weeks before we add a second or third shift to any department. This gives us one more month to look at the sales trend and make sure we need the addition. With unemployment insurance so high, it's important that we don't add workers for short periods of time.

Schedule compliance—Look at our compliance report (left). As orders are received in production control they are scheduled as near as possible to delivery date requested by customer—if there is open capacity during the period. Mostly, production schedules are issued to departments weekly—approximately a week ahead of the time orders are to be produced in departments.

After schedules have been issued, we have to find out how good our schedules are and how well production departments are sticking to them. Our report on compliance with schedule is designed for this. When used right, this report can be one of management's most effective tools for control. We publish it bi-weekly, hand it to each departmental superintendent at regular meetings. A department with less than 90% compliance with schedule for the previous week is expected to explain why it could not produce according to schedule.

This report has revealed various things we didn't know before. For one thing, we found many schedules prepared by production control were not realistic. But because departmental supervisors had to report their reasons for not meeting schedule, we could spot errors and take steps to correct them. Also, because supervisors knew they were held accountable for schedules, they began giving more attention to them.

Various reasons for a department's poor percentage of compliance with schedule come to light from time to time. We analyze these reasons, then go to work on the ones that are causing most trouble. By constantly working on the big trouble-causers, we keep over-all production under control.

Here are some of the reasons for failure to comply with schedule, together with corrective action we have taken:

. . . *Tool failure* caused delays. We have organized a tool-control program (soon to be described in a forthcoming FACTORY article) that has corrected many of our tooling problems.

. . . *High absenteeism* slowed us down. We have eased this situation by having the department superintendent check chronic absentees

DELINQUENT ORDER REPORT

COMMODITY	ORDER COMP. DURING WK.	ON TIME	LESS THAN TWO WKS. BEHIND	OVER TWO WKS.	TOTAL BEHIND THIS WEEK	TOTAL BEHIND LAST WEEK
BRASS FORGING ONLY	40	30	8	2	16	15
FORG. MACH.	26	20	5	1	9	12
AUTO. ONLY	21	17	2	2	7	5
AUTO. B. S.	5	5	0	0	0	0
CASTING	1	1	0	0	0	3
TUBE BENDS	15	9	2	4	1	3
ASSEMBLIES	10	7	2	1	9	5
ALUM. FORG.	3	1	1	1	7	5
ROD	147	119	19	9	36	23
TOTAL	268	209	39	20	85	71

A LITTLE LATE—Delinquent order report shows orders completed each week by each department, number done on time, number less than two weeks behind schedule.

by pulling out the timecards of those off work. The absent employee must get his timecard from the superintendent before starting back to work. This gives the superintendent a chance to talk with him. Our system has worked well in most departments, enabling us to keep absenteeism below 2%.

. . . *Machine breakdowns* gave us trouble. We now have a report, "Machines Down for Repair." It lists all equipment that is down in the various departments. It also states reasons for breakdown and records the date our maintenance department promises for having the equipment back in operation. This report is discussed at our regular superintendents' meeting. Since we started up this report, the number of down machines reported has dropped from an average of 10 or 15 per week to about 3.

Gains from better schedule compliance? They include fewer delinquent orders and better satisfied customers (leading to more business), plus fewer re-runs (meaning an end to costly set-ups).

Delinquent orders—Here's another report (above) that's handed out at the bi-weekly superintendents' meeting. When we first started it up, we found 529 orders behind delivery. This shocked everybody. We figured it would be a real achievement if we could cut down to 20% of 529—or 106 delinquent orders. Fact is, we did even better. Over a period of several months, we whittled late orders from 529 to less than 100.

Our delinquent order report shows the number of orders completed by commodities each week, the number completed on time, the number less than two weeks behind, total behind last week, and total still behind.

Here's how we improved matters:

. . . *Jacked up* attention by supervisors. The report means that all departmental supervisors know the facts about delinquent orders.

. . . *Tracked down* the worst. In our superintendents' meeting it's our policy to ask "Why?" on orders over three weeks late. Works well. When a service department, such as tooling, is blamed for a delay, the department head is present to hear the complaint.

. . . *Set up* a trouble sheet. With it, production control men and department supervisors can follow each order and see the condition of each one that's delinquent.

Trouble sheet—This is a list of orders (opposite page) that are not progressing at a rate that will let us meet delivery dates—or orders that have already missed the dates we promised. It shows order number, part number, quantity, number of weeks on trouble sheet. The "Remarks" column states reason for trouble and present status of parts.

If an item is on the report for the first time, production control's follow-up men follow through. But if it stays any longer, it is brought to the attention of others in our organization. Items on the trouble sheet for four weeks or more go to the vice president in charge of manufacturing or his assistant. Eight weeks or more, to our executive vice president. This way, all manufacturing personnel are in touch with jobs that are giving trouble.

Everybody watches the trouble sheet carefully. It's one of our major tools in expediting delinquent orders. It's like the summary of a baseball game, where errors are printed for all to see.

LINEAR PROGRAMMING

To make the improvements we wanted and expected, we had to make certain changes in the production schedule. With reduction in the cost of set-ups as our primary aim, we

TROUBLE SHEET BRASS SHOP

CUSTOMER	S. O. NO.	PART NO.	AMOUNT ON BACK ORDER	PROMISED DELIVERY DATE	WEEKS IN DEPT.	WEEKS TOTAL	REMARKS
STOCK	553	W-40332	2000	8/1	2	2	DELAYED FOR NEW BRITAIN JAWS. COMP. 9/15
"	1838	W-1009	80,000	8/1	2	2	TO BE STAKED
"	1842	W-1019	30,000	8/8	1	1	TO BE BURRED
"	2714	W-1038	4000	8/8	1	1	" " "
"	913	W-1072	10,000	8/8	1	1	LATE OFF AUTO. TO BE BURRED
"	639	W-1321	7500	8/8	1	1	LATE OFF AUTOMATICS
"	2542	A-2580	1500	8/8	1	1	" " "
"	762	WX-4018	1000	8/8	1	1	LATE OUT OF TUBE BENDING
"	345	W-1320	10,850	7/11	5	5	PARTS TO BE STAKED

REALLY LATE—"Trouble Sheet" lists orders that have missed—or will miss—promised delivery dates. If an order stays long on this list, top management moves in.

instituted linear programming in some of our scheduling.

Linear programming is a technique many people shy away from. It seems complicated. And they're afraid it won't be practicable. But with proper installation and with procedures well worked out, it can be simplified into a routine clerical operation—and still accomplish what you set out to do.

We have adopted a system, known as an index method of linear programming, for scheduling certain of our departments. Our system doesn't give us the best theoretical position or an absolutely perfect schedule. But it does give us a schedule that's more accurate than we derived from any method we used before. We got our system by working with consultants—Methods Engineering Council, Pittsburgh.

Our system of scheduling includes set-up and running time, product types, and product sizes. The index number is simply a ratio of time for doing an operation on one machine to time for doing it on another. By correctly applying the index number, we can quickly determine which job should be transferred from one machine class to another, thus reduce excess hours for any one period to a minimum. (Excess hours are the number of hours over the time the part will take if run on the best machines.)

In most shops equipment is usually added for the purpose of doing a large number of operations faster than with the old set-up. So, if volume of business is good, the amount of work you expect to produce in a week will exceed the capacity of the few latest machines. Therefore you must try to take away from the ideal machine that job or those jobs that will make the biggest cut in excess hours. And you'll run those jobs on slower machines. This way, you'll show a substantial reduction in excess hours.

Results?—Before we put our system to work we created as much as 17% excess hours. But within a few months after we started up our new scheduling, we were staying within 4% of excess hours. Today our figure is down to about 1%. And that's not all. We now have additional hours available for running other orders. Our method enables us to look at our entire schedule at one time rather than at one or two orders.

SHIPPING ON TIME

During the first year we used our reports we found the percentage of orders completed on time amounted to only 54%—and that those orders completed on time, plus those completed less than two weeks behind schedule, totaled only 73%. This meant that of all the orders we shipped, 27% were more than two weeks behind schedule.

The following year we completed 79% of all orders on time—and 93% either on time or less than two weeks behind time. In other words, we shipped only 7% of our orders more than two weeks late.

We believe that by using controls properly, keeping everybody informed about troublesome jobs, and giving attention to first things first, we can still make substantial improvements. We expect eventually to ship 95% of all orders on time.

Big gains at little cost—Don't think we've added a lot of clerical help to gather our data, get our reports together, schedule our work. We haven't.

Fact is, with these reports we can direct everybody's activities better, utilize working

hours better. Why? Because we don't have to go hunting to find troublesome jobs.

Production control develops and issues all reports. They make the job of control easier, because they bring trouble to the attention of department supervisors, make follow-up easy and quick.

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MATHEMATICS SPOTS HIDDEN PROFITS

By Nyles V. Reinfeld, Executive Services, Cleveland

Tube mill gets 15 per cent more out of its machines with more accurate scheduling. Applied to other phases of the operation, programming saved another $350,000 a year.

Linear programming, a high-sounding title for a practical method of production planning, is gaining a growing list of disciples in metal-working plants. Orders are getting smaller, more numerous. Selecting the best of a large number of courses of action is more complicated, more important.

But the average production planner sees linear programming as a tedious and time consuming chore, often requiring large-scale computers and highly trained operators.

Basic Error—It is natural to think that maximum production and maximum utilization of productive machinery are synonymous. In most cases, however, they are not when one spells out the objective mathematically. Here is where linear programming is most valuable to industry.

Setting up such precise definitions frequently reveals that company policies are composed of two or more objectives, all of which are in conflict. The production superintendent who seeks maximum production and insists on keeping all machines busy is generally defeating his purpose. It's seldom possible to do both.

Case in Point—There are over 262,000 ways to schedule a single size of tubing through the plant of a large midwest manufacturer. When you consider that the company makes several thousand sizes of tubing, the combinations are too great for solution by trial and error. In this case, the objective was maximum utilization of the equipment.

Two systems of measuring the work load had been used. The first was to build a weekly schedule on the basis of pounds per week; the second, on the basis of feet per week. The word "schedule" is used loosely. The procedure is to allocate a certain number of pounds or feet to different categories, which are set up on the basis of size ranges. For example, history may show that between the sizes of 1-1/2 and 3 inches the plant has completed an average of 150,000 feet each week. This measure then becomes a scale for future scheduling.

Gathering Data—The only equipment considered in the Linear Programming schedule are the plant's eight drawbenches. They were the bottleneck.

Standard draws for each size of tubing are in layout books. They show the breakdown of the tubing through each draw to the finished size. Layouts also show only the ideal or best bench for drawing a particular breakdown.

Before such data can be used with Linear Programming, it is necessary to make some conversions and additions. A special card was made up for every size tubing, showing every bench for a certain draw and the time it takes.

Programming the Schedule—At this point, all times are converted to time-per-piece and all combinations and possibilities for scheduling a piece are opened up. Time-per-piece is important here. All orders are scheduled by pieces, and the large number of combinations is a fundamental requirement of the programming.

If formal procedure were being followed, next step would be to set up a matrix for solution mathematically. But because of the type of data involved, a fast method could be devised that would give answers within 3 per cent of the best answer. This solution is presently

SCHEDULE CARD

Mix Std.
Size: 500 x .025 Weight: 2.9# Part No.: 3/8 C
Length: 20′ End: 30#

Draw	Pcs. Good	Total Pcs.	Length	General Time/Draw	General Time/Pc.	Group/Pc.	Group	Layout Bench
1		24	31	.912	.038	.038	1	1,2
2		24	31	.980	.041			3
3	3	24	50	1.545	.064	.105	2	3
4		8	19	.672	.084			5,6
5		8	33	1.033	.129	.213	3	5,6
6	4	8	99	1.503	.188			7,8
7		2	22	.745	.372			7,8
8		2	32	1.006	.503			7,8
9(A)	2	2	42	1.500	.750	1.740	4	7,8

Schedule cards are made up for every order and kept on file. Figures in "general time/draw" column are times it would take to make those draws on benches 1 and 2. "General time/pc." is unit time per piece conversion.

being used to schedule the mill. It takes one clerk using an office calculator about 1-1/2 hours per week to solve the schedule.

Building the Schedule—The schedule card (see enclosed sample) is the key factor behind speed of solution. One card is made up for each order as it comes in. When the schedule is to be built, the appropriate card is pulled from the file, and the data is taken from it.

Suppose an order for 100 pieces of 3/8 C were ordered. That schedule card would be pulled and the order entered on the schedule sheet by multiplying the "group/piece" figures by 100 and listing the product according to the layout benches as shown on the example sheet. This same procedure is followed for every order to be scheduled at one time.

With the simplified solution at most only five multiplications are required for each order because of the "group/piece" modification introduced. When the whole schedule is built this way, there will be benches that are overloaded or underloaded. Loads can be adjusted by transferring work to alternate benches without having to refer back to the schedule cards.

Adjusted Schedules—Bench 9 is normally reserved for long lengths. Because it was underloaded on the enclosed sample schedule, it is possible to schedule part 1/2 B as a long length, which is a multiple of the original length scheduled. In this way, bench 9 is

SAMPLE TUBE MILL SCHEDULE

PART	QUANTITY	BENCH #1, 2 TIME	DRAWS	BENCH #3 TIME	DRAWS	BENCH #5, 6 TIME	DRAWS	BENCH #7, 8 TIME	DRAWS	BENCH #9 TIME	DRAWS	
1.050 x .080	1,025	195	1	538	2,3	1,320	4,5					
.625 x .038	500	29	1	81	2,3	934	4-9	742	6-9			
.375 x .034	525	16	1	44	2,3	1,200	4-10	1,090	6-10			
.375 x .030	3,200	80	1	815	2-5	592	4,5	6,650	6-10			
½ A	500	38	1	105	2,3	244	4,5	582	6,7			
⅝ A 3	600	30	1	84	2,3	444	4-6	224	6	366	7	
¾ A 3	1,500	228	1	633	2,3	1,170	4,5			948	6	
½ B	1,150	16	1	174	2-5	128	4,5	2,450	6-11	2,450	6-11	
⅝ B	500	57	1	158	2,3	306	4,5	339	6,7			
1 B	500	76	1	210	2,3	730	4-6	331	6			
												Total
LOAD		765		2,842		6,348		7,571		3,764		21,290
AVAILABLE		3,600		2,900		6,400		7,600		3,800		24,300

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Sample tube mill schedule after overloads and underloads have been adjusted. On the first try, benches 5, 6 and 7, 8 were overloaded so work was shifted.

properly utilized; endage and points are reduced and some handling and machine time is saved.

As you will notice, there is still available capacity on some benches. Present practice is to give the scheduler a list of optional orders to be produced in addition to his regular orders. He selects optional orders to balance out the schedule. Through more precise scheduling of its equipment, the company has been able to increase production 15 per cent.

Other Areas—In a continuation of the above study, evaluation was made of the tube mill products to determine which should be produced, which should be purchased. Study included machine analysis, sales forecasts, shipping costs to all warehouses and profit per piece.

Study showed that profit could be increased by $350,000 over last year by selective purchasing and production with Linear Programming. In another plant, programming was teamed up with operations research to schedule large groups of machines for both running and setup times. Savings were $100,000 a year.

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DO YOU WANT . . . PRODUCTION OR PROFIT?

By Nyles V. Reinfeld, Executive Services,
Management Consultants, Cleveland, Ohio

Manufacturing management is often in a position where it can choose between two roads of action—increase production, or increase profits. The first does not necessarily provide the latter. The difference between these viewpoints was clearly pointed out in a Linear Programming study recently made in the Tube Mill of a large midwest manufacturer.

The study showed that scheduling for maximum profit would increase company profits by close to $350,000 over last year. On the other side of the ledger, scheduling for maximum output would increase the quantity by 22% but profits would decrease 23% below the maximum profit, or about $300,000 a year! This increase in profit was the direct result of a selection of products, using Linear Programming, and is based on the same production costs in both cases. The analysis considered such factors as plant and machine capacity, sales forecasts by various warehouses, shipping rates by items to the various distribution centers, and present and proposed company policies.

THE TUBE MILL STUDY

The problem in the Tube Mill consists of an overload on present production capacity. This overload creates a conflict between Standard and Capped sizes of tubing. The result has been a tendency toward purchasing some sizes of Standard and Capped tubing for resale through the company's various warehouses. Purchased items can be bought at a slight discount; but, after handling costs, they are resold at just about breakeven. In other words, there is no profit in purchasing tubing to fill orders. It is merely done as a customer convenience. The company's customers are serviced by nine warehouses scattered across the country. Due to the increase in shipping costs, the farther the warehouse from the factory, the greater is the tendency to purchase tubing from outside sources close to the warehouse.

The method of supplying tubing to the customer as originally proposed was to manufacture everything for the home warehouse. All Capped tubing for the remaining warehouses was to be bought and resold. Any remaining production capacity would then be used to fill orders for Standard tubing for nearby warehouses. All other tubing would be bought and resold. The pattern, here, is clear. The company was following the logical pattern which would reduce shipping costs and therefore increase profits.

At first view, this seems to be a good policy. Actually, it was not until Linear Programming was applied that it could be shown that a far more profitable policy was possible.

To set the problem up for Linear Programming, it was necessary to gather a large

amount of data about every machine in the plant and about every product to be produced on the equipment. In some cases, the data was not directly available and had to be developed.

The plant handled several thousand products which represented many variations of approximately a hundred standard sizes of tubing. Each piece of tubing passed through a series of operations such as the piercer, pointers, saws, annealing furnaces, draw benches and straighteners. In many cases, it passed through some operations several times. On the draw benches, for example, some pieces of tubing required as high as 13 separate draws in bringing them down to size.

BASIC PRINCIPLES

Clearly, there are machines and factors that do not play a material role in determining which products should be produced and which should be bought. One of the problems, therefore, in formulating the attack, is to determine which data is essential.

The philosophy that underlies the application of Linear Programming to the Tube Mill problem is based on the concept of a bottleneck. A bottleneck is a condition which limits the total plant output. The bottleneck may be a certain operation or a group of operations or machines. In the case of the Tube Mill, draw benches limit the tube capacity. All other functions of that department, such as sawing and piercing, are limited in their output by the draw benches. Most of these "before-and-after" operations are working six or eight hours a day, while the benches are busy continuously, around the clock. Everything we can get through the benches, we can easily get through the rest of the department. Therefore, the bottleneck determines the ultimate profit that we can make by operating the Mill. See Figure 1.

We can increase the dollar output of the bottleneck in two ways: We can buy new equipment and enlarge the capacity at the point of the bottle neck, or we can increase the earning power of the present equipment.

We can relate profit to time in the bottleneck. Last year approximately 1,400,000 minutes of draw bench productive capacity was used on standard tubing. If the profit from standard tubing was about $1,000,000 last year, the company made $.714 for each minute the draw benches were operating. If we could increase this to $1.00 per minute, the company's profit for the year would be $1,400,000.

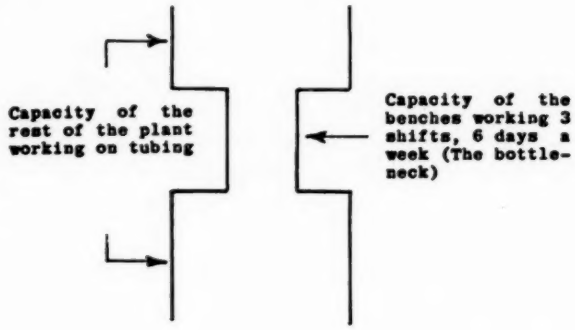

Figure 1.

You will soon see how it is possible to increase the profit-per-minute by means of Linear Programming.

What is true of profit is also true of production. If we wish to increase the quantity through the bottleneck, we must then work in terms of quantity-per-minute. In either case, it is possible to achieve a considerable increase, without any change in equipment. (This statement is not intended to minimize the importance of equipment modernization, methods improvement, etc.—when necessary.)

To increase the profit-per-minute involves the concept of opportunity profit. Opportunity profit is the increase in profit that can be made by running one part instead of another, and is determined by the profit-per-piece divided by the pieces-per-minute. It is seen from this fact, that the piece with the highest unit profit will not necessarily give the highest profit-per-minute.

Let us exaggerate this concept for purposes of illustration. Suppose that one piece of tubing makes a profit of $6.00, with a running time of 10 minutes. The profit-per-minute would be $.60. Another piece of tubing may make a profit of $5.00, with a running time of 8 minutes. In this case the profit-per-minute would be $.625.

In other words, if we could sell all we could make of either product, we would make the greatest profit by making the latter item. That

such cases actually exist in Industry is shown by the solution we arrived at in the case of our Tube Mill example (see Table I). It is more profitable to make some items for the West Coast and pay the shipping cost than it is to make others for the home warehouse. The same thing is true for home warehouse items only—namely, some prove to be more profitable than others, without direct regard to the unit price tag attached to each.

SOLVING THE TUBE MILL PROBLEM

Working with the basic principles just discussed, the first step, after isolating the bottleneck equipment (draw benches) was to gather the relative data and organize it into a coherent picture.

Gathering the data essentially amounted to getting a list of the benches, utilization figures, available time on each, a list of all the tubing produced in the Mill, a standard operational breakdown for each size, and a list of all the equipment alternates and times for making each single draw. Since time was given in terms of draws, which represented any number of pieces, it was necessary to determine the number of pieces that were involved in each draw. In this way we were able to get the time per piece per draw.

A list of the warehouses, and sales forecasts by warehouses by products, were obtained along with shipping rates and the profit-per-piece at the plant before shipping costs were deducted. Whereas profit is normally based upon total cost variance including shipping charges, what we need is the profit at each specific warehouse.

Shipping rates were given in terms of weight minimums and destination. The rates for a specific destination were then deducted from the factory profit on each product to give the profit at each warehouse.

The next step was to set up the matrix for solving the problem. (A matrix is a mathematical arrangement of the coefficients of algebraic equations). Figure 2 shows a part of the simplex matrix as it appears for one size of tubing and the three warehouses requisitioning that particular product.

The matrix is designed to convert normal profit into opportunity profit, and to compare for profitability of producing various products. We don't know what the opportunity profit is by direct inspection, because we don't know what combinations of machines will be used to make the products. The only approach is to solve all possible combinations of time, profit, and product that are relevant to obtaining the best answer.

The matrix in Figure 2 would normally require solution by electronic computers. It is possible, however, to perform a transformation on the data which will convert the matrix to a method suitable for hand calculation. The transformation is possible because of the type of data involved. The new (distribution) matrix, Figure 3, is much simpler to work with. In some instances, the distribution matrix can be set up directly without actual construction of the simplex matrix.

In constructing the distribution matrix, the vertical columns are arranged in descending order by relative profit. In scheduling the utilization of available capacity to meet forecast requirements, assignments are made on the matrix, working from left to right—giving priority to those product orders having the greatest relative profits. The complete conversion of the simplex matrix required two weeks, at which time the answer was obtained directly by setting up the distribution matrix, without further solution.

The rules for performing these operations are quite simple and can be readily taught to clerical workers.

The peculiarity of the data which made this type of matrix solution possible is the fact that there is a bottleneck within the bottleneck machine group. This bottleneck exists on the last four machine groups. When these machines were loaded, there was still open capacity on the first machines. This meant that we could solve the problem for the smaller bottleneck and then finish using our capacity on the first machines with products that can be made on them alone.

Caution must be exercised in working with bottlenecks of this sort since there is a tendency for the bottleneck to shift as the mix changes. In this case, were the mix to change over a period of time to where the first machines became the bottleneck, then the present solution would no longer be valid. However, since this solution is for a year in advance, it would normally be safe to assume that a

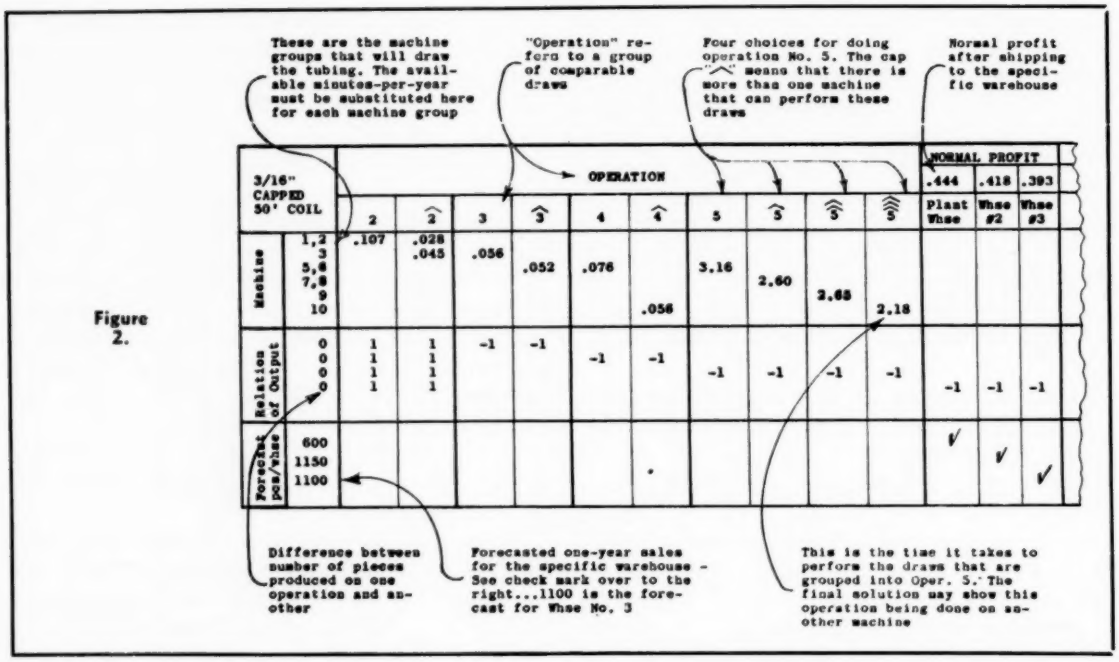

Figure 2.

regular pattern of sales would not affect it. In the case of other plants that have been analysed, bottlenecks of this type have shifted from week to week.

DIFFERENT SOLUTIONS

In arriving at the solutions, we approached the problem from the standpoint of the forecasted sales and also from the standpoint of both increased capacity and expanded sales forecasts. We will not go into how these variations were handled other than to emphasize the generality of the final answers.

In arriving at the solution of what products to make and which to buy, we ended up with a priority of products. This priority lists the most profitable products first and the least profitable last. A part of this table is given in Table 1. It will be noted that warehouse No. 3 items are included right down the line with home warehouse items, despite the difference in shipping costs. It will also be noted that the profits-per-piece are not directly aligned with the profitability as indicated by the priority.

Because of the general approach that was used, the answers obtained cover a wide range of variation in sales and capacity. The solution is true for the present capacity as well as the expanded, and has the additional virtue of considering the course of action to pursue as sales increase. Since the answer is given in terms of priority of one product over another, quantity and capacity determine only how many of the products on the bottom of the list are to be purchased. In other words, on the basis of the load ahead of the equipment, the overload is purchased from outside sources in order of lowest priority.

Price changes affecting profit on one single item will require special analysis of that one product, which will probably be shifted in the priority table. Cost changes affecting all products equally, such as increases in pay scale, generally will not affect the status of the priority table.

Several different solutions were made for comparative purposes. These solutions were given in terms of a list of products, such as the ones shown in Table I, and II. Products were listed by priority and showed what should be produced to accomplish a certain objective. In all cases for comparative purposes, the same capacity and forecast figures were used.

Similar tables were made up showing comparisons of the highest-possible profits with last year's production (Table III) and with the

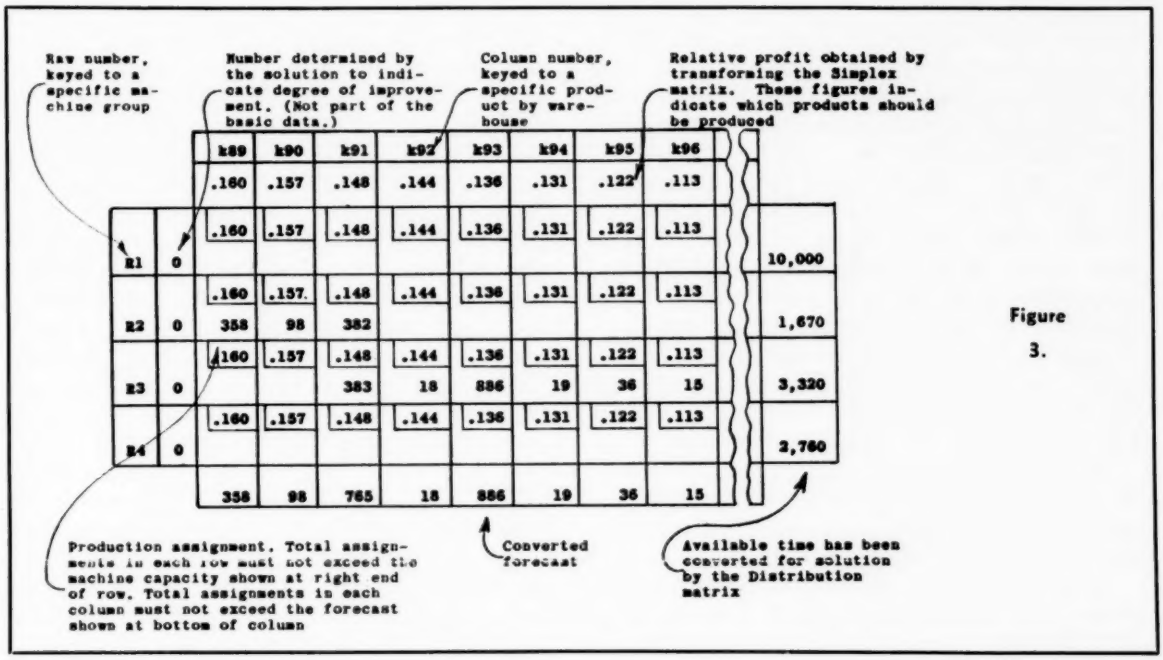
Raw number, keyed to a specific machine group
Number determined by the solution to indicate degree of improvement. (Not part of the basic data.)
Column number, keyed to a specific product by warehouse
Relative profit obtained by transforming the Simplex matrix. These figures indicate which products should be produced
k89 k90 k91 k92 k93 k94 k95 k96
.160 .157 .148 .144 .136 .131 .122 .113
R1 0 10,000
R2 0 358 98 382 1,670
R3 0 383 18 886 19 36 15 3,320
R4 0 2,760
358 98 765 18 886 19 36 15
Production assignment. Total assignments in each row must not exceed the machine capacity shown at right end of row. Total assignments in each column must not exceed the forecast shown at bottom of column
Converted forecast
Available time has been converted for solution by the Distribution matrix

Figure 3.

TABLE I. HIGHEST-PROFIT PRIORITIES

Product*	Location (Whse)	Priority	Profit/Pc. /Whse
1-1/4B3	2	10	4.50
1-1/4B	1	11	2.03
1-1/4A3	1	12	4.48
1-1/2A	2	13	2.23
1-1/2B	2	14	2.20
1-1/4B	2	15	1.85
1-1/4A	1	16	1.89
1A3	1	17	3.99
1-1/4B3	3	18	3.94

*A partial list of all the products, arranged in order of the priority applicable when objective is to use present capacity for making highest profit.

TABLE II. HIGHEST PRODUCTION PRIORITIES

Product*	Priority†
1-1/4B	4
1-1/4A	5
3/4B	6
1C	7
3/8A	8
1/2B	9
3/4A	10

*A partial list of all the products, arranged in order of the priority applicable when objective is to increase output.

†No distinction made as to location, since profitability is not considered.

proposed method of purchasing which was outlined earlier and designed to reduce shipping costs.

It was found that shipping costs are not a major factor in determining maximum profit. This is shown by the fact that use of the highest-profit table would increase profits by $300,000 over the original proposed policy and by $350,000 over profits realized by last year's production. The $300,000 profit increase constitutes the cumulative opportunity profit. This profit is not realized by cost reduction or by increased production, but solely by the opportunity profits of all items considered simultaneously.

TABLE III. COMPARISON OF RESULTS*

	Table I (Highest-Profit)	Table II (Highest-Production)
Pieces Produced	820,000	1,000,000
Increase in Pieces		180,000
Profit Produced	$1,300,000	$1,000,000
Increase in Profit	300,000	

*Based upon use of same capacity.

CONCLUSIONS

The findings and data, that we have just discussed, are ready for use as soon as the final report is handed in to management. In spite of the rather complex mathematics involved, the only requirement on the part of management is that they understand the use of the tables.

With these tables, it is possible to work from either the highest profit or the production table (depending on your objective) to determine the whole program for the coming year. Once a policy has been established, it is a simple matter to refer to the table when making a decision between producing or purchasing.

All the profit figures are based on present capacity and forecasts. Naturally, as sales and capacity are expanded, the same possibilities exist on a larger scale.

As a follow-up to the profits study, Linear Programming is now being used in the Tube Mill to build weekly schedules for maximum utilization of equipment. This type of program ties together the allocation procedure and the scheduling phase, which are normally treated separately.

The profits study is just one example of the many ways in which Linear Programming may be used to increase company profits or reduce costs. This type of approach can be applied to any industry which has the problem of making outside purchases to supplement their line, or the comparable problem of subcontracting many of the components for an end product.

Linear Programming is being used successfully for a wide range of management problems other than direct profit studies. Examples include salary evaluation, production scheduling, inventory control, and market research.

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HOW YOU CAN USE LINEAR PROGRAMMING

By N. V. Reinfeld and B. L. Hansen
National Institute of Management

Here's the story, A to Z, on Linear or Mathematical Programming, with an approximation technique that makes it practical for many plants, many problems. Case studies, specific instructions detail this modern cost-saving technique so you can use it.

Let's start from ground level and work up towards the peak in explaining Linear or Mathematical Programming so you can use it. Vagueness and generalization seem to have hindered broad entrance of the technique into industry. Yet, it is a needed and versatile tool for everyone who operates a factory and must have precise, quick answers to problems of scheduling, inventory control, tooling, material handling, peak demand, distribution, etc.

To understand Linear Programming, you must know:

1. What it is.
2. When and where you can use it.
3. How it works, depicted concretely in actual case studies of production problems you are likely to encounter.
4. How it can help you.

WHAT IS LP?

Linear or Mathematical Programming can be defined as a mathematical procedure for solving management problems. It involves consideration of several to many alternative courses of action to select the most desirable.

WHEN CAN YOU USE LP?

National Institute of Management's extensive experience has evolved a set of principles to help determine when LP can be applied to plant problems. Necessarily generalized, the principles proved suitable to every client problem analyzed by N.I.M. They follow:

1. Your problem must have a number of alternate choices or different ways of taking action. For instance, you must have a choice of

machines to make a part.

2. A difference in the rate of efficiency must exist between choices. One machine may take longer or involve higher costs than another. This difference in efficiency determines how much improvement you can gain with LP.

3. Your problem must have a definite upper limit. For example, each machine has only so many hours a week available for scheduling. This ceiling can't be exceeded.

4. A floor is also needed in the problem. These lower limit requirements state what you must accomplish. You may have to produce so many parts.

5. You must define your goal. What do you want—most profit, lowest cost, least production time, highest utilization of equipment, or even greater customer satisfaction? Though these objectives may sound similar, they are not usually alike. You may program a part to run in the shortest time without assuring largest profit.

6. Factors in your problem must be interrelated—or have a connecting link.

7. Problem factors must also have a common unit of measure—or a common denominator to permit evaluation. Herein is a frequent handicap to LP. All data are not normally given in common terms but must be converted for LP. Converting to a common unit of measure permits a more realistic reappraisal of data. This suggests improvements not apparent before.

Most plant problems can be neatly adjusted to the above principles. For some others, use imagination to establish conformity.

Another word to the wise: A purist's approach to LP can prove very time-consuming for common problems. But the technique's entirely feasible through use of simple approximations that can be solved quickly, even by clerical workers. *The approximation technique is used in solving the problems presented in this report.*

Though not as utterly true as solutions reached with purely formal LP methods, approximation solutions are much superior to those obtained with non-LP methods.

MACHINE SCHEDULING WITH LP

Where should we start in explaining how LP functions? Machine scheduling offers a common problem area.

Usually, production orders are assigned first to the ideal machine or group of machines. When an ideal machine is loaded, jobs filter down to slower or non-ideal machines.

Thus, jobs channeled from the loaded ideal machines to the non-ideal machines are performed at higher than ideal rates, creating excess production time and costs. The total effect of such excess time, or the difference in job production time between the ideal (fastest) machine and the non-ideal (slower) machine, is called "opportunity cost," which can be minimized with LP. Objective is scheduling orders on ideal and non-ideal machines for lowest total excess time.

Here's how this concept might work out:

Order	Machine A	Machine B	Machine C
8402-A	88x	86*	
9640-B	90*		99x
8301-A		85x	180*

"*" = Hours actually spent in machining. Total = 356 hrs.
"X" = Machining hours under Linear Programming.
Total = 272 hrs.

Hours saved = 84 hrs.

Without LP, the first two jobs were performed on ideal (fastest) machines for no excess time. Third job (180 hour) was produced on non-ideal Machine C at high excess, when compared to 85 hour on ideal Machine B. Total affect is poor.

Under LP, "X" numbers show where jobs should have been placed for lowest total excess time. By producing first two orders non-ideally and the third ideally, 84 hours were saved. (This example was extracted from a case involving more than 150 orders. The three jobs depicted were scattered among the others.)

Despite a common misconception, LP is not intended to load as many orders as possible on fastest or ideal machines. Rather, the technique strives to place orders to attain minimum total excess time and cost.

In the early installation of LP, plant people often believe production time is rising because more orders are scheduled on non-ideal machines. But when it's proved that the precise

AN ACTUAL SCHEDULE OF MANUFACTURING

(Similar examples are typically found with automatics, chucking equipment, forge presses, and other operations. Many installations of LP to these areas are presently in use.)

Type Mach. Order	4 Spindle Acme	1 Spindle Cleveland	B & S OG	6 Spindle Acme	B & S 2G
1	158	335X			
2				58	43X
3				22	21X
4				91X	
5	36			37X	
6	28	53X		29	
7				39X	56
8	36X	65			
9			26X	34	
10		210		89X	
11			20X	18	
12				11	9X
13				14X	20
14		14X			
15			11X	13	
16		39X		26	
17			25X	22	
18			83X		
19				19X	23
20		174X		128	
21					39X
22	19				18X
23		38X		39	
24		33X			
25					
26		18X	5X	20	
27		14X		15	
28					6X
29				77	86X
30				98X	112
31				18	16X
Actual Time Required	36	839	170	394	251
Time Used By LP For Same Work	36	738	170	387	238

Savings: 121 Hours

Underlined numbers show where work was actually performed.
An "X" after a number indicates where LP scheduled the job.

Fig. 1

order reshuffling of LP reduces overall time as much as 20%, they become converts.

SETTING UP FOR LP

Before plunging into an actual LP case study in scheduling, let's consider preliminary planning. First, you'll have to do some paperwork, listing what jobs can be performed on what machines and how long each job takes on each machine.

In doing so, you are defining the alternative courses of action and preparing measurement data for LP.

It's not as laborious as it sounds. Past records will show which machines produced what parts and how long they took. Next, all orders and their time values are listed in a simple table called a matrix. It spells out every alternate possibility of producing your jobs.

Figure 1 is a slide of a total schedule worked out this year at a government installation. Only five machine groups are involved here—but LP saved 121 hours in one week.

Underlined numbers in Figure 1 show where work was actually performed. An "X" after a number indicates where LP scheduled the job. Through the use of Indicators, a valuable time-saving tool of LP, this problem was solved in the following way:

1. Every order was assigned to its ideal machine.

2. The production time workload of every machine was added up. (Naturally, machines were overloaded.)

3. This workload was compared to available capacity.

4. Indicators were developed by dividing production time of a part on an ideal machine into the time for doing the work on an alternate machine. These indicators were listed next to alternate times in the table. Then job overloads were transferred from the overburdened ideal machines to next best machines on the basis of the indices.

"Cheapest" transfers are made first, progressing to the most expensive. For example, an order with an 1.01 indicator would be transferred before an order with an 1.5 indicator. As mentioned before, purpose of the order shifting is to attain lowest total excess time.

With indicators, large schedules have been solved weekly in about three hours. They have been used to solve matrices for minimum production time, minimum cost, maximum profit, and maximum machine utilization. With LP, you can also swiftly take into account secondary times introduced through variations in primary operations.

There's nothing hard and fast in this, but LP savings on from 100 to 150 machines should be about $100,000 annually. The heavier your workload, the larger your potential savings.

WHAT MACHINES TO CHOOSE

Your springboard to broad application of LP can be the machines currently in your schedule. After the system's taken root, ferret out more and more machines which can be used as alternates on your jobs.

You may discover, as one plant did, that number of machines under LP rose 25% in a short time. The more alternate choices, the better.

You can exclude certain machines with no alternates, alternates with equal efficiency, and machines not affecting the major workload.

Later, you may broaden the area of LP scheduling by bringing in other machines from other departments. It's natural to segment a plant into departments which are scheduled individually. LP helps evaluate costs, and indicates whether machine regrouping is advantageous.

In seeking the largest number of machine alternates, you will expand the production flexibility of your plant while improving its methods. In six months one machining plant found new alternates for over 200 jobs. And in adapting jobs to alternates many methods improvements were instituted.

This plant uses the telltale number of excess hours created by a job as a clue to its need for better methods. It also balances costs of new tooling against excess production hours it creates to help determine its value. Repetition of orders is also checked to show whether a number of low excesses in a year will help offset tooling costs.

LP can assist in machine purchase policy. Records of excess hours due to lack of capacity on ideal machines indicate how much can be saved with new equipment. An exact procedure can be set up, showing which machines should be purchased and how soon

they'll return their investment.

SCHEDULING TOOLING SET-UPS

To further clarify the versatility of Linear or Mathematical Programming, let's explore its application to another common area of production—the scheduling of machine set-ups for minimum time.

For simplicity's sake, let's describe an LP system for a single operation shop—such as automatic screw machines. Scheduling for a diversified machine shop will be complicated by more operations and set-ups, but LP procedure will merely be an extension of the one used for screw machines.

For automatic screw machines, set-up changes involve cams, gearing, collets, tooling and adjustments. How much time will be spent in changing a set-up for a new job depends on the set-up of the job currently in the machine. LP seeks to put orders in the proper sequence for the lowest total set-up time.

That's not so simple. A multitude of set-up choices are available. But because of the numerous alternate choices, set-up scheduling falls within the scope of LP.

How was such a job accomplished? Set-up characteristics for automatic screw machines were analyzed. Five set-up characteristics were chosen to represent certain classes of set-up changes. Two characteristics were common to most automatic departments—stock size and thread roll. Another three were added because of their importance. The following table resulted:

Setup Characteristics	Machine Changes	Type Machine 6 Spindle	5 Spindle	4 Spindle	Hours for Change in Setup
Stock Size	Collets, Pads and Adjustments	4	3	2	
Thread Roll	Thd. Roll, Shavetool and Adjustments	7	6	5	
Die Head	Cams, Die Spindle, Gear	8	7	6	
Tap Size	Cams, Thding Attachment, Gear	8	7	6	
Cycle Time	Cam, Gearing, Adjust Tool Holder, Auxiliary Adjustments	5	4	3	

Note that the above table gives set-up characteristics, the machine changes involved, and hours needed for changes on three types of machines.

Thus, if you can run jobs with matching characteristics successively, you will save the number of hours indicated in the table. For instance, four hours will be saved if two jobs with the same stock size are run in sequence on a six-spindle automatic.

Excepting cycle time, which depends on the machines used, set-up characteristics are taken directly from the part blueprint. Though hours for set-up changes in table are representative and may vary from actual hours needed, they will average out with fair accuracy over a period of time.

How good is the table? One firm used only stock size and thread roll set-up characteristics to save from 100 to 150 hours per week. With inclusion of the three other characteristics, savings were doubled.

Naturally, different set-up characteristics are needed for different machines and machine combinations. Several hundred set-up hours per week were saved by a machine shop using a comprehensive list of characteristics.

MECHANICS OF SCHEDULING

Now that you have the fundamentals, let's work out a typical set-up scheduling system. Following is the completed card that begins the system:

Stock Size .625X	Thread Roll .625F18	Die Size	Tap Size (p=pipe tap) .250p
Part A 5901	Qty: 32,000 pcs.		
Machines	58	16	62	
Cycle Time	7.8	7	6	Cycle time in seconds
Total	69	62	53	Cycle time in hrs
S. U.	21	33	35	Complete setup time in hrs
Total	90	95	88	Total Production time in hrs

As an order is received, set-up characteristics are taken from the blueprint and

recorded in appropriate slots at top of the card. Part number and quantity are also recorded.

Cycle times or production times per piece are obtained for each alternate machine. Also recorded are estimated set-up times for each alternate machine. These times assume that a complete set-up is required. For convenience, set-up times have been noted in layout books next to cycle times.

In the Stock Size slot at top of the card, the "X" after numbers indicates hexagon stock. The "F" in the Thread Roll slot indicates a fine thread (U.S. Fine)—18 threads per inch. Die Size slot is blank because no die threading is needed.

To save set-up hours, certain set-up characteristics must agree. In matching Stock Size of one job with the one shown on the above card, both jobs must agree as to size and shape of stock. Further matching of any of the other set-up characteristics will bring greater savings.

Two jobs may prove identical in stock size but not in thread roll. To estimate savings, you would refer to the set-up characteristics table and check the set-up hours opposite Stock Size, under the appropriate number of spindles.

When a card has been prepared for a job, it is filed under the week it is to be produced. At week's end, a buff colored duplicate card is reproduced for every job that will enter production next Monday morning. White cards for that week are pulled from the file and added to the buff. Cards are then grouped for matching set-up characteristics. A key sort card can accelerate this grouping procedure.

Since parts of the same stock will usually run on the same machine, Stock Size characteristics are grouped first. After this, other grouping combinations are developed gradually breaking down the cards into small groups of orders to be scheduled on individual machines.

From one to two hours will be needed to group cards for 150 orders. It should be remembered that all cards cannot be grouped together. You may have a large number of independent orders and some other groups.

But at this point you should have a shrewd approximation of a minimum set-up solution. Some orders will match in three or four set-up characteristics. Others will show smaller savings.

Now that individual cards have been put into groups, new cards are made for each group. These show total time, minus set-up savings, needed to produce a group of orders.

Order groups are then applied to a Linear or Mathematical Programming schedule (matrix) and solved for minimum total time, using the LP scheduling procedure discussed earlier.

While scheduling you may note that some set-up savings will be less than running-time savings. It will be best to break up such set-up groups and produce the orders separately to save running time. Refinements to the above system will come with practice.

Once again, it should be mentioned that LP approximation techniques have been used in example problems. But if mathematical equations were developed for these problems, a high speed computer would be needed to reach solutions in feasible time. Nevertheless, approximation solutions are sufficiently accurate to yield good savings.

Mathematical equations can be written so that all variables have values of zero or one. This feature lends itself readily to computer solution. Only addition is involved, an extremely fast operation for computers.

SIMILAR FOR MACHINE SHOPS

The scheduling example for automatic screw machines is similar to that used for machine shops. When several operations are involved on a part, a separate card is made for each operation. These separate cards are located independently in the set-up grouping—except that the order of performance must be considered.

Rush orders and breakdowns play havoc with scheduling. Both these factors can be quickly included in an LP schedule at any time to determine what job assignments should be changed to assure least overall production time. Without LP, rush orders and breakdowns often shove jobs on the first available machine. It may prove better to tear down a job already assigned and move it to another machine than to assign a rush order arbitrarily.

Rush orders create many excess hours. LP can stem the waste.

In the problem discussed, LP was employed for minimum production time. The same

methods can be used to solve problems of minimum cost, maximum profit, other objectives.

LP FOR HANDLING, PEAKS

LP can also perform well in areas affiliated to direct production.

Material handling is a prime area for savings, involving one of the simplest applications of LP.

Much the same methods of distributing shipments cross-country by truck can be used in solving small scale handling problems.

The many facets of peak production demand and producing highly seasonal items also are susceptible to LP. Objective is least total production cost. Many diverse elements must be considered, including a typical sales forecast, plant capacity, given storage areas and costs, manufacturing costs, overtime pay, inventory handling, etc.

LP will consolidate and coordinate all components of the problem to produce the best overall answer. It can show at what time production must be initiated to prepare for peak demand, how much to stock of the item, how much overtime will be needed, if any, and whether it's better to hire men under GAW and have some idle time, or whether it's better to hire a minimum force.

WHAT PRICE LP?

How much time you spend in installing an LP system depends on accessibility of the data you will use.

Early in an LP system, some time must go to research and practice. But after a system has been installed, subsequent systems are introduced far more smoothly.

To gain acceptance of people involved in a new LP system, a short indoctrination course may offset many later woes.

Less tangible but important benefits of LP are heightened output, improved evaluation of machinery and tooling, improved customer deliveries.

Inventory management or control is another fertile field for LP, which can bring together a larger mass of data for simultaneous consideration than has ever been possible before.

Other applications of LP, either in effect or under consideration, include distribution, marketing, advertising, and salary evaluation.

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VAM: VOGEL'S APPROXIMATION METHOD

By Nyles V. Reinfeld, Managing Director, Executive Services
National Institute of Management, Inc., Cleveland 14, Ohio

If your first encounter with Mathematical Programming was at the hands of a mathematician, you might very well have been tempted to substitute a D for the V in the title on the basis of its relationship. But the title is correct as given.

The three letters V-A-M stand for Vogel's Approximation Method. Mr. W. R. Vogel developed the VAM while working with me in setting up a training program in Mathematical Programming for the Federal Government.

The VAM is offered as a simplification and short cut over other methods currently in use.

The method is very simple to learn and is exceedingly fast compared to conventional methods of solution, making it very suitable to industrial adaption. Whereas conventional methods of solution require formal training, the VAM can be learned in a matter of minutes, thus eliminating the bugaboo of mathematics found in industry.

Based on our experience, the VAM will give the best answer to applicable problems in about 80% of the cases. In the other 20%, it will usually give a very good approximation to the best answer. In these latter cases, it usually removes the "cream" of the savings to be obtained.

In addition, the VAM solution can be used as a starting point for applying conventional solutions reducing the total solution time to as much as one-fifth of that normally required.

Hence, the value of the VAM is two-fold:

1. It is easy to teach and has a quick-solution time.
2. With the solution obtained, you have a good point at which to apply more precise techniques, if the exact answer is required. again saving considerable computational time.

The problems to which the VAM applies are the typical transportation or distribution problems, which represent the bulk of all presently known applications of Mathematical Programming (MP). Many such problems exist in the normal traffic, production control, and inventory control activities of the average manufacturing establishment.

A CASE STUDY

To illustrate the technique, let us take a look at an actual problem that was encountered at Joliet Arsenal. The problem deals with tractor-trailer movements and involves the distribution of 63 trailers to various locations for purposes of picking up loads for further distribution.

Rather than consider the complete problem here, we will only consider the problem of returning the trailers after they have been unloaded.

If a department is shipping 8 trailer loads out each day, then one requirement is that 8 empty trailers must be available at that department each day to pick up the loads. The Joliet problem was further complicated, as in industry, with the use of railroad shipments, thus upsetting the balance of shipments by trucks between buildings. In other words, it was possible to haul 15 trailer loads of material out of a building each day, while only bringing in 2 trailer loads each day. The other material needed at the building was supplied by rail.

The problem of getting empty trailers back for loading is formulated below in the "Trailer Return Table," Table I.

Along the top of the table are listed those departments and buildings that receive truck shipments daily and therefore will have empty trailers available from which to draw. The number of empty trailers that will become available during the day at a particular building is shown at the bottom of that column. For example, at Bldg. 64, 18 empty trailers will be available each day.

FROM / TO	1	3	64	27	NEEDED
27	-33	-25	-23	0	20
62N	-12	-26	-23	-20	7
62S	-10	-30	-20	-27	12
66	-45	-26	-50	-18	3
1	0	-24	-19	-33	7
3	-24	0	-22	-25	14
AVAILABLE	15	27	18	3	63 / 63

TABLE I
Trailer Return Table

Along the left side of the table are listed those departments and buildings that make truck shipments daily and therefore need trailers delivered to them. The number of empty trailers needed during the day at a particular building is shown at the far right of that column. For example, Bldg. 66 will need 3 empty trailers each day.

The figure in each of the little squares represents the time (in hundredths of an hour, based on time study) to move an empty trailer from the building designated at the head of the column to the building designated at the left end of the row. (Because, in this example, the material being moved included ammunition, the distances between buildings were naturally fairly great.) The minus sign in front of the figures merely means that time is to be considered as costly, rather than profitable.

The problem, here formulated, represents a typical problem encountered in industry in which it is desired to reduce the total material handling time to a minimum.

METHOD OF SOLUTION

The subsequent tables in this section show the method of solution using the VAM. Please note that the VAM method of solution starts with the table in the form given by Table I and, by a series of repetitive cycles, gradually makes assignment (by rows and columns) until all needs are met. Each cycle involves a series of steps which are repeated in exactly the same manner until the answer is obtained.

In the example given here, seven cycles are required to get the final solution. The first three cycles are illustrated by Tables II, III, IV, and the last four cycles by Table V. (In actual practice, you would work with just one table and build upon it.)

To distinguish between the cycles, in each table a screen has been thrown behind the steps taken in that particular cycle. While you are first applying VAM or demonstrating it to someone else, it may be helpful for you to use a different color pencil for the action taken on each cycle. Thus: Red can be used for cycle 1, Blue for cycle 2, Black for cycle 3, Green for cycle 4, etc.

In addition, each step within a cycle has been indicated by an appropriate symbol. These symbols are described in the step-by-step formulation below:

STEPS WITHIN THE CYCLES

Step 1 (Symbol: "Difference" column and row added to the basic table, as shown in Table II). For each row in the basic table, look at the time (cost) figures in that row and take the difference between the two smallest of these times. (If the problem were one that would provide for maximum profit, then positive figures would be used, in which case take the difference between the two highest profits.) Write this figure at the right of the row in the "difference" column.

For each column, look at the time-figures in that column and take the difference between

	Col. 1	Col. 2	Col. 3	Col. 4		
FROM / TO	1	3	64	27	NEEDED	Diff.
Row 1 — 27	-33	-25	-23	0	20	23
Row 2 — 62N	-12	-26	-23	-20	7	8
Row 3 — 62S	-10	-30	-20	-27	12	10
Row 4 — 66	-45	-26	-50	-18	3	8
Row 5 — 1	0	-24	-19	-33	7	19
Row 6 — 3	-24 ×	0 (14)	-22 ×	-25 ×	14	22
AVAILABLE	15	27	18	3	63 / 63	
	10	24	1	18	Difference	

TABLE II—Cycle 1
Trailer Return Table

the two smallest times (or two highest profits). Write this figure at the bottom of the column in the "difference" row.

Compute these differences for all rows and columns.

Step 2 (Symbol: □ , a square enclosing a "difference" figure). Checking visually both row and column differences, select that difference which is greatest. The largest difference in cycle 1 of our example (see Table II) occurs in a column, and therefore the figure, 24, in the "difference" row is enclosed in a square.

Step 3 (Symbol: ○ , a circle enclosing a figure). In the column with the largest difference (24 in Table II), assign the maximum number of trailers to the lowest cost (or highest profit). This step is illustrated in Table II by 14. Note that the lowest cost in column two is zero, hence the assignment is to be made in the block that contains that zero. In other words, it costs nothing to move trailers from Bldg. 3 to Bldg. 3. But when we determine how much to assign, we must check to see how many trailers are available and how many are needed . . . in order to arrive at the number to be assigned. In cycle 1, we find that 27 trailers are available at Bldg. 3. Since we need 14 trailers at Bldg. 3, we assign 14 — entering that figure in the column and encircling it.

If the greatest "difference" as indicated by a square had occurred in a row instead of a column, the assignment would have been made to the block in that row with the lowest cost (or highest profit). Hence, the procedure in either case is the same.

Step 4 (Symbol: X). When we assign trailers as indicated in Step 3, we will use up all of the trailers (available or needed) in either a row or column. In Table II, the assignment of 14 trailers to column 2, row 6, takes care of the full needs of Bldg. 3 and no more trailers need be borrowed from any other point. Hence, we cross or x-out row 6, indicating that we have used up its capacity.

SUCCEEDING CYCLES

We are now ready to start cycle 2 and we follow exactly the same steps as those above. The only change encountered is that the basic table is treated as existing of only those parts that are not x-d out (and we ignore the "difference" column and the "difference" row that we created on cycle 1). In other words, in our example, row 6 is not included in the calculation of differences for cycle 2. This will be true also in each subsequent cycle: Each time a row (or column) is crossed out, the differences are calculated only on the basis of the remaining parts of the table.

Table III shows the continuing process of what has gone before and also gives the steps used in the second cycle, as indicated by the screen background. A new "difference" column and a new "difference" row are constructed. In this case, the largest difference occurs in row one. Hence, 3 trailers are assigned to the cheapest cost (zero) in row 1. Three trailers use up all the capacity of column 4, so it is crossed out. Since 20 trailers are needed at Bldg. 27 and only 3 trailers are available there, we will have to transfer 17 more trailers to Bldg. 27 from some other point.

The differences for the third cycle will now be based upon the part of the table that has not been x-d out by the previous two cycles. The steps for the previous cycles and cycle 3 are shown in Table IV.

In cycle 3, the largest difference again occurs in a row. In fact, there is a tie between row 4 and row 5. Row 5 is selected because it has the lowest cost of the two tied rows. A number of rules have been developed for handling special cases of ties, but they will not be included here since this article is only intended to illustrate the simplicity and practicality of the technique.

The succeeding four cycles follow exactly the same pattern as that just illustrated and are given complete in Table V. Because the differences will normally change with each cycle, it is important that each cycle be completed before going on to the next. The simplicity of the procedure, however, is apparent and the actual time involved for large problems is not too great.

Recently, one problem involving a table of 37 columns and 13 rows was solved by Mr. R. W. Metzger of the GM Institute using the VAM. He estimated that, with proper application, problems of this size would take about two hours to solve by the VAM once the table was set up. The table given in our example, here, although similar, represents the total size of the problem worked on at Joliet. The figures

	Col. 1	Col. 2	Col. 3	Col. 4			
FROM / TO	1	3	64	27	NEEDED	Diff.	Diff.
Row 1 — 27	-33	-25	-23	0 (3)	20	23	23
Row 2 — 62N	-12	-26	-23	-20 ×	7	8	8
Row 3 — 62S	-10	-30	-20	-27 ×	12	10	10
Row 4 — 66	-45	-26	-50	-18 ×	3	8	8
Row 5 — 1	0	-24	-19	-33 ×	7	19	19
Row 6 — 3	-24 ×	0 (14)	-22 ×	-25 ×	14	22	None
AVAILABLE	15	27	18	3	63 / 63		
	10	24	1	18	Difference		
	10	1	1	18	Difference		

TABLE III—Cycle 2
Trailer Return Table

are the original figures of the study that was initially made.

In cycle 5, we encounter something new. The greatest difference exists in row 2, where we need 7 trailers for Bldg. 62N. Since trailers from Bldg. 1 (column 1) would provide the least time factor (−12), we should draw from that point. However, running down column 1 we find that we have already assigned 7 trailers of the 15 available. We still have 8 left, of which 7 can be assigned to Bldg. 62N, writing the figure 7 in row 2, column 1.

Coming to cycle 6, the greatest difference exists in column 1. We need 12 trailers for Bldg. 62S (row 3), but only 1 trailer of those originally available in this column remains to be assigned. Therefore, we do not x-out the remaining squares in row 3, since we will still need 11 more trailers for Bldg. 62S.

After cycle 7, there are two blocks indicated by the heavy rectangle in the table to which no assignment has been made. Bldg. 27 still needs 17 trailers. Since all options with respect to the table have already been taken, there is no choice; we merely assign the remaining capacity to these two blocks as shown. Once this has been done, the answer so obtained is an optimum. In other words, no other method for handling these trailers would be better in terms of time.

INTERPRETATION OF THE SOLUTION

The solution says that since Bldg. 27 will have 3 trailers during the day, it will use these 3 trailers to fill part of its needs of 20 trailers a day. Bldg. 64 will send 7 of its 18 trailers to Bldg. 27 and 11 of them to Bldg.

	Col. 1	Col. 2	Col. 3	Col. 4				
	FROM / TO	1	3	64	27	NEEDED	Diff.	Diff.	Diff.
Row 1	27	-33	-25	-23	0 (3)	20	23	[23]	2
Row 2	62N	-12	-26	-23	-20 X	7	8	8	11
Row 3	62S	-10	-30	-20	-27 X	12	10	10	10
Row 4	66	-45	-26	-50	-18 X	3	8	8	19
Row 5	1	0 (7)	-24 X	-19 X	-33 X	7	19	19	[19]
Row 6	3	-24 X	0 (14)	-22 X	-25 X	14	22	None	None
	AVAILABLE	15	27	18	3	63 / 65			
		10	[24]	1	18	Difference			
		10	1	1	18	Difference			
		10	1	1	None	Difference			

TABLE IV—Cycle 3
Trailer Return Table

62S, and so on.

The solution can be carried one step further by setting up routes showing the actual paths of loaded and empty trailers, if desirable. Such an extension permits a more accurate measurement of daily load in terms of tractors needed to haul the trailers, it permits a balancing of loads between drivers, and it permits a wide variation of sequencing so as to accommodate changes in schedule, delays in loading or unloading and priorities, without affecting the optimality of the end result.

Changes in the solution, reflecting change in the number of daily movements of trailers from building to building, can also be made in a matter of minutes.

CONCLUSION

The method of solution just discussed extends itself to solution of any type of Mathematical Programming problem which would be classified as a distribution problem. Since these types of problems represent a very high percentage of all Mathematical Programming problems, the VAM has a wide range of application.

The problem selected here does not illustrate all facets of the VAM. Special consideration must be given to ties and other analoguous situations for which a number of rules have been devised.

Again it should be noted that the method is

	FROM / TO	Col. 1	Col. 2	Col. 3	Col. 4	WEIRD	Diff.	Diff.	Diff.	Diff.	Diff.	Diff.	Diff.
Row 1	27	-33 ×	-25 (10)	-25 (7)	0 (3)	20	23	[23]	2	2	2	2	2
Row 2	62N	-12 (7)	-26 ×	-25 ×	-20 ×	7	8	8	11	11	[11]	None	None
Row 3	623	-10 (1)	-30 ×	-20 (11)	-27 ×	12	10	10	10	10	10	10	[10]
Row 4	66	-45 ×	-26 (3)	-50 ×	-18 ×	3	8	8	19	[19]	None	None	None
Row 5	1	0 (7)	-24 ×	-19 ×	-33 ×	7	19	19	[19]	None	None	None	None
Row 6	3	-24 ×	0 (14)	-22 ×	-25 ×	14	22	None	None	None	None	None	None
	AVAILABLE	15	27	18	3	63 / 63							
		10	[24]	1	18	Difference							
		10	1	1	18	Difference							
		10	1	1	None	Difference							
		2	1	3	None	Difference							
		2	1	3	None	Difference							
		[23]	5	3	None	Difference							
		None	5	3	None	Difference							

TABLE V—Cycles 4, 5, 6, 7
Trailer Return Table

an approximation and does not guarantee the best answer. The answers obtained are best in about 80% or more of the problems encountered so far. Sometimes, it is necessary to "polish" off the solution by use of some of the more sophisticated mathematical techniques currently in use in the field. However, even when the "polishing" is felt to be necessary, the VAM offers a short cut and solution-time savings of considerable value. When the VAM solution is best, it can be checked mathematically in a matter of minutes.

Mr. Bert Kassing of the Nekoosa-Edwards Paper Company, in discussing one of his problems, estimated that the VAM took about one-fiftieth of the time normally required by experienced persons with the mathematical method known as the MODI (Modified Distribution Method), the method most frequently used.

Because of its simplicity, we believe that the VAM will do much to foster the spread of Mathematical Programming into industry by making it a tool that everyone can use without a great deal of extensive study. In addition, it will make MP practical in those situations where time is an important factor and a computer is not a personal piece of equipment.

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SYSTEMS FOR MANAGEMENT CONTROL and NEW TOOLS FOR MANAGEMENT CONTROL

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SYSTEMS FOR MANAGEMENT CONTROL

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EARLY in 1958 J. W. Forrester of M.I.T. wrote an article for the Harvard Business Review which reads in part as follows:

> "Management is on the verge of a major breakthrough of understanding how industrial company success depends on the interaction between the flows of information, materials, money, manpower, and capital equipment."
> "The new management concepts will rest in part on recent advances in data processing . . . improved understanding of decision making and experience in analyzing and simulating the characteristics of complex systems, and . . . on 20 years of research in information feedback systems."

My comment at this stage nearly three years later is that we still seem poised on the verge of the major breakthrough predicted at that time but in many ways appear no nearer than in 1958.

We speak of major new concepts and major new data processing tools but somehow our daily business lives aren't as radically different in 1961 as we thought or hoped they might be back in 1958. It is true that our credit cards have numbers on them which are read by optical scanning equipment, our personal checks are embossed with magnetic ink characters and our telephone and electric bills ask us to send in a punched card to insure proper credit. There are, however, mechanical or electronic devices applied to routine bookkeeping and clerical work. For those of us in business systems work the systems concepts don't go very far beyond those of some years ago and only the equipment used is different.

CONCEPTS AND PRACTICAL APPLICATION

Our discussion will deal with basic management control concepts and progress towards their application in business life. There is, indeed, a natural lag between concepts and practical application. This should not surprise us. The concepts of communication using missiles or earth satellites are discussed and understood but a long ways from being applied. Systems concepts utilizing improved mathematical inventory formulas, computers and nationwide communication networks can be foreseen as leveling business cycles but these concepts probably won't affect our economy importantly for many years.

Even the initial application and realization of new concepts somehow usually falls short of our earlier visions. There is such a sorry contrast between the idea of men gliding between planets in jet propelled space suits and the cramped astronaut going a few hundred miles up in the air and back in a space capsule that we wonder if the entire dream of man in space has any meaning. There is usually a similar contrast between the first computer output on a new operations research project and the plans, projections and hopes of those who launched the project perhaps months or years previously.

We can see, however, a fundamental difference in the lag which exists between concepts of space travel and their realization and the practical application of new concepts for the control of business as envisioned by Forrester. The difference is that the tools for space travel are just being conceived and developed. The practical tools in terms of computers and communication systems needed for a fundamental revision of our business practices are,

however, available and with us now and we need only to learn to apply them.

A few years ago it seemed to those of us in the systems and data processing field that if we only had this piece of machinery, this gadget or one or another special devices on the computer, we really would get somewhere. Today there is hardly a gadget or device thought of a few years ago which is not available or will not soon be available at a surprisingly low cost. It appears, however, that our ability to use these new tools has been restricted and confined to the clerical areas where mechanization and other cost reduction schemes of one kind or another has flourished for twenty years. We are, it appears, able to apply the computer and related tools to the single problem of high cost in the area of clerical work but there is a disappointing lag in applying these same tools to the broad problem of business planning and management control.

CLERICAL COST CONTROL

We indicated that computers are being applied rather generally to routine clerical work. While the assigned topic for today does not deal with the use of computers for clerical work, by way of further introduction, we may discuss the question, "Are electronic computers the answer to clerical cost control?" My answer is an unqualified "Yes."

The answer of "Yes" is not based on the individual success or failures in computers taking over such work as payroll, budget records, accounts payable, inventory records or billing. We can note, however, that, with present equipment, a systems study of the clerical work involved in any one of these areas for a plant or company of reasonable size will show at least a break-even or a savings. As the size of the job increases, the profitability of computer application goes up proportionately and to some extent exponentially.

Placed in a perspective pointed toward the types of computer equipment we will be installing a year or two from now, or shall we say the "second generation" of computers, the answer is "Yes" with no question. Firm specifications and reasonably firm prices indicate that for each computer dollar we will spend for the second generation of computers the productivity per dollar will be many times that of today's computer. In other words, if today the large-scale computer at a cost say of $200 per hour can profitably take over routine clerical work, it doesn't take much arithmetic to figure what will happen when the cost per hour stays the same or decreases and the speed increases by as much as ten times.

Just because faster and cheaper computers are on the way does not mean that all clerical work should be rushed pell mell to computer processing. No matter how fast the machine, if an application is poorly planned, inadequately justified and improperly controlled, it will yield only problems and loss no matter how productive the computer. It's sobering to remember that the computer which does 1,000,000 calculations a second is also capable of making 1,000,000 mistakes a second. We can, however, summarize our discussion of clerical computer applications by stating that, coupled with good systems planning and effective organization, the computer is the answer to high cost in the clerical area and each passing year will increasingly demonstrate the validity of this statement.

EVIDENCES OF MANAGEMENT CONTROL

If we accept the proposition that for the future computer application can be assumed for routine record processing and clerical cost control, we can return to the basic topic of systems for management control. We have asserted that progress towards implementing new systems concepts using computers and other data processing tools outside the clerical area is disappointingly slow.

Before exploring this assertion from the standpoint of an industrial company, let's look at it from the point of view of our everyday lives. We have noted that our credit cards, our bank checks and our monthly bills all bear evidence of new tools and techniques in clerical records work. But are the businesses servicing us correspondingly better run or managed and do they serve our needs any better than they used to? I doubt it.

Have you ever had the experience of asking several times for a particular kind of salad dressing at a well known local department store and being told that it's no use to come in so often because the first letter of the supplier's name starts with an "R" and it will be

some time yet before the "R's" come up in the alphabetical ordering system?

Does the man who fixes your automatic washing machine carry the 25 or 50 most used parts or do you have to pay for two calls if a part is needed? Have you, as I have, waited June and July to get a part to fix a power mower bought from a nationally recognized company?

Has the plant or department where you work ever been shut down one week and so overtime the next or vice versa? Is a production line in your plant ever filled up producing for inventory or over-stocks on one item when a backlog of customer orders exists for another product which can be built on the same line?

These are not problems in inventory control, in engineering, in production or in sales. These are problems in management control. In every instance I mentioned, something was happening just the opposite from what management wanted--in other words--management was not in control. Management had set up or permitted to be set up systems which were yielding results which in specific detail were opposite to the wishes of management, that is, management was not running the system but the system was running management.

It's quite common these days to blame management because it fails to set up systems to accomplish its stated objectives and is unaware of the new concepts and tools at its disposal. As an example, a recent editorial in Management and Business Automation stated as follows:

> "Without a doubt the greatest need for education still remains at the top management level. There must be better understanding of the true potential of systems and management by exception. Executives have to learn that computers in particular are not just high paid accounting machines designed for faster preparation of a payroll or sales statistics. The survival of their company in the competitive years ahead may well depend on their realization of the fact that a computer using simulation techniques, can project the company's future under any number of varying circumstances."

I don't feel, however, there is any point in blaming management for lack of awareness or lack of a system. Rather, it would be well to look at the systems concepts which those of us responsible for systems work offer to management. In each case, the concepts must be examined to see if they are useful to management in controlling the business or whether they pose alternative systems even more difficult for management to control and guide towards the ultimate objectives of the business.

CONCEPTS AND TOOLS

In the more specific area of our discussion which follows we will illustrate the point that the systems concepts and detailed systems work necessary to organize and effectively control a single production plant are applicable to the control of large and complex business organizations. In other words, the problem of management control of a physical production plant is directly paralleled in the problem of establishing effective management control over the functionally oriented organizational aspects of a business.

As we proceed with our discussion it may be helpful to bear in mind the general management control concepts which will be illustrated. Essentially, any control problem whether for a single plant or on a divisional or corporate level resolves itself to the following factors:

- Specific and detailed definition of objectives - an effective control system must force the definition of objectives.
- Fixing of responsibility - this must be personal and not general.
- Reporting of performance - this must be timely and recognize both the objectives established and the responsibility fixed.

The tools used may include a micro-wave communication system and large-scale computers or they may involve a mimeograph form and time stamp at a plant operating station. The techniques may range from mathematical models depicting cash flow for a major company or a daily chart covering going and downtime on a punch press. The virtual

explosion in developing new tools and techniques is, however, hollow if the fundamental concepts for an effective system are forgotten.

In addition to the concepts involved, I think we will see that effective systems control action is specific rather than general, detailed rather than approximate and tedious and grubby rather than glamorous.

DEFINITION OF MANAGEMENT CONTROL

Instead of getting into the various academic definitions of management control, let us attempt to define management control or lack of management control by a concrete illustration.

My first assignment of any consequence in the business world was as a production engineer in a newly constructed process chemical plant. It was just getting into operation. Simply speaking, things were out of control because nobody from top management to the foreman on the floor had any detailed or definitive picture of what was going on in the plant.

This plant was highly automated and designed as a single almost continuous process. Essentially four or five different chemicals came in at one end of the plant and presumably a given amount of finished goods was expected to go into barrels at the other end of the plant. The basic question which had to be answered was "What was happening in between."

The plant output was a fraction of what was expected based on the weight of various input chemicals if you cared to trust the monthly accounting records. In addition to material losses in the plant, the finished goods warehouse started getting filled with material, with chemical properties or contamination which caused quality control rejections. Added to that was material returned by customers which had somehow gotten by quality checks. Equipment breakdowns and quality control rejections led to late shipments to customers and lost business.

There are a number of general things that suggest themselves as appropriate management action at this point. From a top management level the answers might be to sue the consulting engineering company which designed the plant, fire the plant manager and call in some new consultants. Any one or all of these actions might be appropriate but let's lower our sights a little and take a look at the specific problems in the plant.

ILLUSTRATION OF MANAGEMENT CONTROL

At the risk of gross over-simplification I could generalize and say that we had a plant designed to accomplish its productive purpose but somehow designed without control points from which progress could be judged. At the obsolete plant which the new plant replaced, each portion of the operation was handled by a separate type of machine, quality and material volume was checked at each handling and discrepancies reconciled then and there. At one stage of the operation, where a reasonable comparison was possible, it was found that $20,000 more of material was lost each month at the new plant compared with losses at the old.

It's not my purpose here to take you on a verbal trip through a chemical plant but a few specific points are worth noting.

At one stage, the chemical tank operator repeatedly forgot to introduce a stabilizer in the tank at the right time and the chemical would set up in the pipes and tie up the whole operation. I'm sure you are now thinking that the introduction of the chemical should be automated but it wasn't quite that simple because the amount of stabilizer depended on the pH or acidity of the solution and automation of this type involving feedback is expensive when you need an operator anyway. The answer was simple, a mimeographed form and a time stamp was set up for use each time the stabilizer was added and one problem was put under control very effectively.

The problem of material losses is ideally met by weighing input and output at various stages and accounting for discrepancies. This type of control costs time and money to install in an automated plant. A simpler answer is to weigh the losses swept or shoveled up, identify them as to source and keep records. A reasonable set of this type of records takes much of the mystery out of the material loss figures the accountants report

each month. The records also point the way to the specific areas in the plant most urgently needing correction and, incidentally, provide the cost justification for proposed engineering modifications in equipment.

Improper chemical properties and contamination is far less complicated to correct if arrangements are made to take material samples off the system at reasonable intervals and act upon each problem that shows up.

Management control in the plant situation I have described is essentially a problem in communication to make sure that control information is identified with those responsible for action plus the requirement that there also exist, formally or informally, a set of standards or defined objectives against which to judge a product at a particular in-process point as acceptable or not acceptable. If not acceptable, the responsible operator, the foreman or the plant manager must be in a position to decide what to do about the situation.

I have illustrated some of the specific action steps taken to move a plant operation from confusion and loss to a productive and profitable plant. In essence it was necessary to define specifically what a product should be at each stage of production, to identify those responsible for achieving the product specifications and to prepare timely control records showing production, performance and losses identified as to objectives and responsibility.

Each one of you who has been associated with a plant operation will protest that what I have said is too simple and too neat. I admit this immediately. You will tell me that in a real-life chemical plant the smell and feel and look which the experienced operator can apply to his product may go well beyond the chemical properties which can be identified and measured in the laboratory and I will agree with you. It is possible to go a step more and state that there may be differences between the settings and readings of various tanks and ovens in the summer as against the winter or for a rainy day compared with a dry day.

Regardless of the exception, the subjective smell and feel of the operator or the vagaries of the weather, we must all, however, agree that the most essential factors for effective control of a plant are product specifications as objective as possible, explicit definition of responsibilities and timely and meaningful communication and reporting.

INTRINSIC AND EXTRINSIC FACTORS

These essential factors so readily accepted and understood for control of a tangible plant operation unfortunately get clouded, obscured and made immensely complicated when applied to broader management control problems where something beyond the physical operation of a plant is involved. We cannot claim that all the factors going into an annual sales projection can be recognized as fully or the results as neatly predicted as is possible with a tank of chemicals. We can easily see that the factors affecting the outcome of a chemical batch are largely intrinsic, that is directly related to the ingredients and physical processing conditions and only incidentally extrinsic, that is affected by weather, humidity or other external factors.

We are aware that the variables affecting the preparation and realization of a sales projection may be only partly intrinsic or related to factors under control of the management concerned and largely extrinsic or related to external factors in the competitive market or the economy as a whole. This does not, however, invalidate the comparison with a plant. The well controlled plant seeks to establish and achieve specific standards for all intrinsic factors under its control and also to measure and compensate for all extrinsic factors. The general objective of scientific management as espoused by Forrester or others in the field is to apply numeric and mathematical disciplines to areas of business activity now generally under subjective and discretionary control.

The objective of numeric and mathematical discipline applies to both the intrinsic factors where direct action is possible and also to the extrinsic factors where a business cannot change the factor measured but must instead react to factors not under its direct control.

THE DIRECTION AND THE TECHNIQUES

In the control aspects of a business, as has already largely taken place in the plant, we are moving from subjective to objective control,

from general and approximate objectives to specific objectives, from opinions and judgments to statistics and mathematical formulas, from weeks or months old performance reporting of past facts to day by day control reporting of current facts. The interrelationships of a business within itself and with the facts of outside economic life have in the past been thought of almost as artistic and judgmental factors but are more and more being seen as definable, measurable and far more predictable than has been assumed in the past. These facts may have been known all along, but the knowledge had little meaning without computers and related tools to make possible correlations and calculations as well as communication far beyond that feasible in the past.

The techniques used to achieve the general objectives identified with the so-called "management science" so much in the forefront today normally go under the names of operations research, simulation, integrated data processing, computer control, etc. Use of these techniques is not an end in itself. Their full potential value can only be realized in a business when the techniques are placed in the broader perspective of management control.

CONCLUDING SUMMARY

In our introductory comments we noted that the basic ingredient for an effective control system are specific and defined objectives, fixed and personal assignment of responsibility and reporting of performance to recognize both the objectives established and the responsibilities fixed.

In our discussion we have seen that whether we are speaking of a plant production problem or a sales forecast, it is necessary to establist specific and detailed objectives. For those who have never done it in a plant, this looks easy but in actual life establishing and administering specifications all down the line which will result in an acceptable production volume, cost and quality is not an easy job.

To determine a sales forecast or a divisional budget plan may look like a simple guess to those not involved but for those responsible it may appear a hopeless task because of the many factors which can't be controlled. Whether controlling a plant or projecting a sales forecast or a budget, the basic necessity is for specific and detailed objectives with responsibility for achievement fixed on a personal basis. These ingredients plus a communication and reporting system which locks in both the planned objectives and the responsibility for their achievement are indispensable for effective control. In the plant, automatic production recording equipment can be used for control purposes in exactly the same way as a communication system and computers can be used in the control of a multi-plant operation.

We have thus seen that for the plant operation illustrated in our discussion and for the broader control problems with which we made our comparisons, the control concepts are the same, only the tools used and the level of control are different to meet different requirements.

By way of conclusion, we might return to a point made earlier and almost in passing. We said that effective systems work required specific rather than general action, detailed rather than general analysis and tedious rather than glamorous undertakings.

An effective plant system is built out of detailed attention to an understanding of hundreds of operations. The new management concepts which we noted at the outset of our discussion hold potential for a major contribution to the success of American business but they cannot be implemented on a general or an approximate basis. They must be built on an understanding of the mechanisms and interrelationships of management control which go far deeper than those we have today. For progress in this field, it is necessary to remember the concepts used in improving plant efficiency and begin to invest the same amount of talent and attention to the analysis and detailed understanding of the mechanisms in our management control processes as we are already investing in the engineering and control of our physical plant operation.

NEW TOOLS FOR MANAGEMENT CONTROL

By A. C. NESSE

Manager, Data Processing Department, Ford Division, Ford Motor Company

MANAGEMENT control can be defined as any means by which management makes sure that a business or any aspect of a business operates in conformance with its wishes.

The tools and techniques used by management to achieve control will vary with the size and complexity of the organization and function to be controlled. In the one man shop, control of the operation is incidental to the performance of the work. As the one man shop grows the total control requirements may not go beyond the direct personal supervision of several employes by the owner and perhaps periodic accounting reports for income tax or other purposes. When, however, the size of the control problem grows beyond the area which can be kept under the personal and direct supervision of one individual, we immediately introduce the need for procedures, schedules, reports and meetings.

When control systems start to become formalized we introduce the problem of reports and paperwork. A business does not produce or sell paperwork. Its basic responsibility is to produce and sell goods. Paperwork exists not as an end itself but as a necessary means of communication indispensible for controlling an operation. When we look at the input and output of Engineering, Manufacturing Control, Sales, Purchasing or the Controller's Office, we see that the entire input and output of these areas of the business is basically paperwork or communication. Actually, only the manufacturing, assembly and distribution areas of the business handle the tangible product involved.

We might also note that regardless of how simple or how complex a business or a control system is, the basic concepts are the same. For the one man shop, for the individual plant or for a multi-plant business as a whole, effective control consists of establishing a set of specifically defined objectives, fixing direct responsibility for achieving the objectives and establishing a communication and reporting system by which performance is judged to recognize the objectives desired and the responsibilities fixed.

Since so much of our business life is oriented around the receipt and the disbursement of paper it often is hard to recognize that management control applied to paper alone will never produce a product or change an operation. Paper exists and has value only insofar as it makes a contribution to producing a product, selling it, moving it, distributing it. Yet it is not practical or possible to attack a paperwork problem simply as a paperwork problem. All paperwork must be related to the function which it serves, the needs which it fulfills and the tangible action which it may accomplish.

MANAGEMENT SCIENCE

For lack of a better term, perhaps we can say our subject could appropriately be titled "Management Science for Management Control" instead of "New Tools for Management Control." Under the general title of "Management Science" it would be possible to lump all the techniques, skills, tools and equipment which distinguish present day and future means of controlling a business operation from the intuitive and personal control of some years ago. For a general definition of management science I would like to parallel a definition of automation suggested by James R. Bright of the Harvard Business School some years ago. He defined automation as any means of carrying out productive operations which is more automatic and less manual than that generally characteristic in the past.

We might say then that management science

is any means of planning and controlling a business or any aspect of a business which moves toward objectivity, quantification of subjective factors and automaticity. Wherever we substitute mathematical formulas for an opinion, wherever we substitute a punched card for a sheet of paper, a magnetic tape record for a punched card or a short exception report for a detailed printed report, we may say we are practicing management science.

For purposes of our discussion I should like to discuss two aspects of management science --operations research and data processing. I shall attempt to distinguish between the two as well as establish the relationship between these two aspects of modern management control.

OPERATIONS RESEARCH AND DATA PROCESSING

It is now generally accepted that operations research is directed towards the analytical and decision-making aspects of management control. Operations research is normally distinguished by mathematics, formulas, relatively elaborate statistics and the use of high sounding words such as stochastic, heuristic, algorathmic, homeostatis, stuttering poisson, triple exponential smoothing, etc.

Operations research usually but not always involves the use of computers and usually but not always may involve a good deal of horse sense. I am reminded of the remark by L. H. C. Tippet, Statistician to the British Cotton Industry Research Association that statistics must be approached with a mind that is open but not empty. Certainly the same is applicable to a successful practice of operations research.

The data processing aspect of management science or management control involves the systems and methods studies and the computers or other equipment necessary to convert the masses of data characteristic of a business enterprise into meaningful information and reports. The reports presumably should point towards providing management with the information necessary to control the business towards the objectives management has established.

We now come to a self-evident question, "What is so special about operations research or the so-called "new" management science which puts it so much in the public eye today?" I suggest that the principal new factor is new tools for operations research and analysis--i.e. computers.

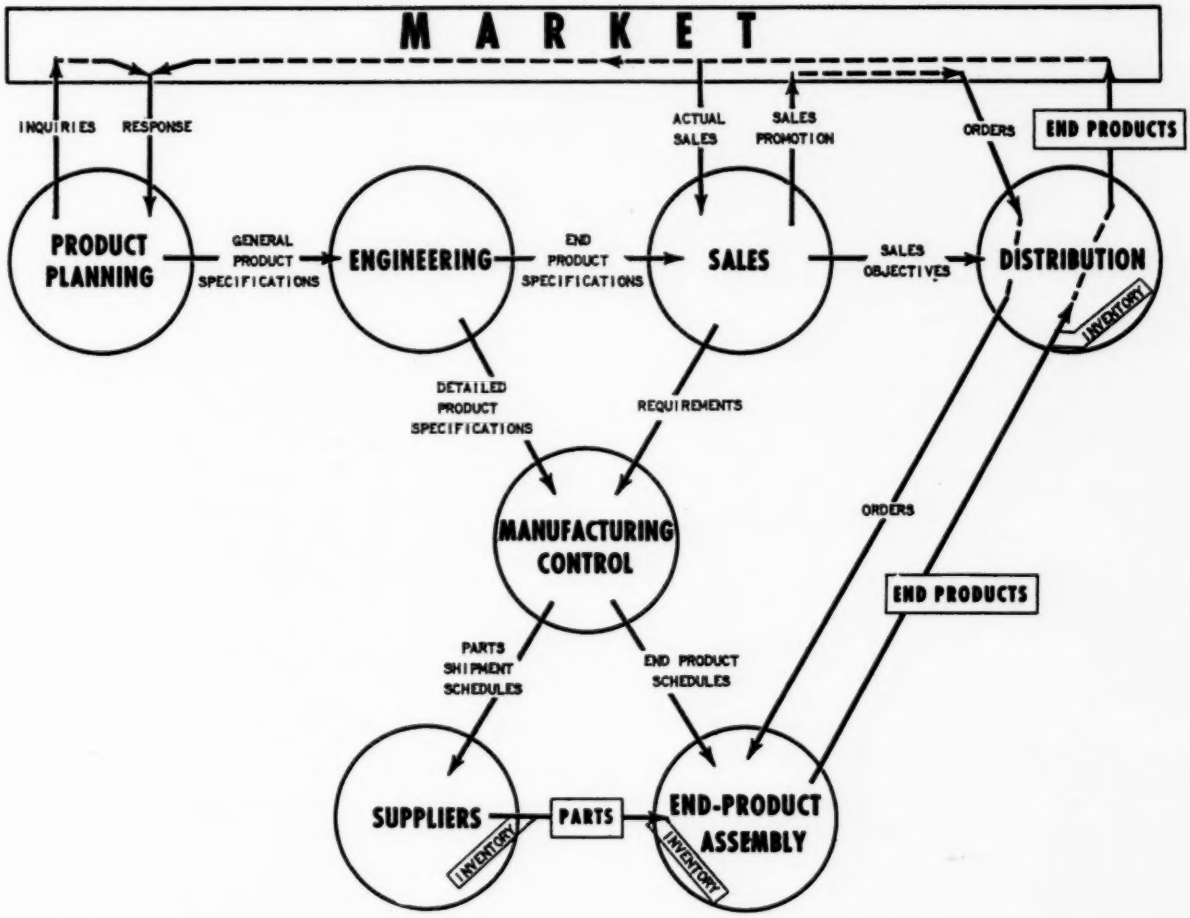
Turning now to our definition of data processing and recognizing that data processing today is in essence the systems and methods work we have known for many years, we again ask the question "What is the reason for the emphasis and attention given to data processing today?" The answer for data processing is the same as for operations research, newer and vastly more powerful tools for processing data and reducing it to meaningful information, i.e. computers and related date processing equipment.

New operations research techniques and data processing tools are in fact so powerful that they make it necessary to re-evaluate the entire concept of management control. A few years ago decentralization was virtually necessary for a large company because central management could not possibly assemble and correlate all the data necessary for timely and effective decision making and action. Today we may have many good reasons for decentralized management control but the ability to provide control information is not one of them. Well designed data processing systems including wire or wireless transmission of data to a central control point with large-scale computers to distill and classify the data make decentralization for reasons of management control obsolete.

In our more detailed discussion we will review a chart showing the areas in a company's operation where the new concepts and tools apply now or will be applied in the future and we will review a second chart which illustrates the application of new techniques and tools in a highly centralized manufacturing and sales control system.

THE FUNCTIONAL VIEW OF A BUSINESS

So far in our presentation we have viewed the general aspects of new management science techniques but have not viewed the various areas of a business where they are applicable. Our understanding will be improved if we now review a chart showing the general functions involved in a typical business and see where the most progress has been made towards



applying new concepts and techniques and where further progress can be anticipated

The chart should not be confused with an organization chart which is, after all, an entirely different way of looking at a business. From an organizational basis, we would have to add such activities as Industrial Relations, Finance and Purchasing. We would also perhaps see Product Planning and Distribution under Sales, and Engineering functions would probably exist in both Sales and Manufacturing as well as in a separate Engineering activity. Manufacturing Control might exist as a separate organization, but it might also exist as functions scattered to Engineering, Sales and assembly organizations.

Regardless of how a company is organized, the systems man must look beyond the organization chart and see the functions performed and fit them into a meaningful pattern of communication and control relationships for the business as a whole. As we go through our chart we will note where the newer systems concepts and other developments in so-called "management science" or operations research and data processing are applicable or will be applicable next as progress is made.

PRODUCT PLANNING

This is the most creative and least well-defined area of any business enterprise. My own personal feeling is that in many businesses the paperwork carried by activities which are basically creative and imaginative can be a serious burden and can hurt the basic objectives of the Product Planning function.

Conventional systems work of the paperwork simplification variety can be a real contribution to Product Planners. Eliminating and

simplifying reports and loosening of the details of reports, requisitions, etc. to recognize the character of the work performed should be considered in the systems approach to such an area.

Another contribution which can be made to Product Planning is applying mathematically and statistically valid techniques to the preparation and analysis of inquiry instruments or questionnaries used to test the market. In other words, creativity in Product Planning must be disciplined by valid statistics and reasonable reporting requirements but controls and reports beyond those to assure proper performance of the assigned function should be minimized.

The chart shows general product specifications being transmitted from Product Planning to Engineering but it is self-evident that there actually exists a two way communication, a pattern of inter-action rather than a one-way street.

The forms and procedures applicable to effective communication and control often grow up in a haphazard manner and, of course, deserve systems study and formalization to the mutual advantage of Product Planning and Engineering.

ENGINEERING

For purposes of this presentation the application of engineering computational work to computers is excluded. Some companies may use the same computer for engineering computations as is used for commercial record processing but aside from the overlap occasioned by joint use of equipment the use of computers for engineering or technical work is completely separate from the systems concepts covered in this discussion.

We have all heard engineering activities described as a "paper mill" and I think it is characteristic that there may be three or four clerical and administrative employes for each professional engineer. Often, however, little significant investment is put towards developing effective communication and control systems for an engineering activity. There is little unique in the record keeping and control reporting requirements of engineering. Bills of material and other parts records must be maintained, requisitions issued, blue prints reproduced and distributed and engineering specifications forwarded to Sales, Manufacturing and possibly to suppliers.

For effective control of engineering work we can accept the general control principles that objectives must be defined, responsibility fixed and performance or progress reported. We must also agree that the beginning and end of engineering is paper, that is, general product specifications are received on paper and detailed product specifications or engineering releases and prints are also paper. This point applies to engineering as a whole and also applies to completion of work in the various areas within the engineering function.

When we get behind the general concepts of effective control in engineering work we get to the subordinate but still important point of technique for control. In the automobile business, as is well known, lead time of more than a year is characteristic and extremely tight control of each aspect of the engineering work is necessary. There are essentially two techniques applicable:

One technique is to require each responsible activity to report periodically progress in its respective area. The periodic reports are then pulled together for management review and action is taken where indicated. I would describe this as equivalent to the plant manager's occasional tour of the plant which is an excellent way to find out what's going on at a particular time but if not supplemented with other control techniques, is a poor way to control a large and complicated plant operating perhaps three shifts and week-ends. A control system such as this may be mechanized, integrated and the reports prepared on a computer but it suffers because it is periodic and because the reports and work involved are in addition to other paperwork such as prints and releases which are basic to the engineering process.

The second and much preferred control technique is to make control reports the by-product of regular and unavoidable paperwork indispensable to the engineering process. This technique is equivalent to posting schedules at each

plant station and providing for regular reporting of performance. By this approach, control is continuous and variations are noted before they interact with other areas of the plant.

What we are saying is that a control group handling assignments, schedules, prints and releases on a service basis and probably using computers or other equipment can function as a paper processing service activity to relieve engineers of unnecessary work and can at the same time provide the basis for effective management control through progress reports and special off-schedule reports as required.

For purposes of this presentation, we can assume that routine volume clerical work will eventually all be performed by computers. It's only a matter of time and normal progress before punched card equipment and computers are applied to the bulk of clerical and control work for all large or medium size engineering activities. A good place to start is in the area of output data from Engineering, that is, in the transmission of end-product specifications to Sales or detailed product specifications to Manufacturing Control as shown on our chart. When these are transmitted in the form of punched cards, paper tape or magnetic tape, we can assure accuracy in the use of the specifications by Manufacturing Control and can take out the cost and time otherwise required to keypunch or convert engineering data into a form usable by Manufacturing Control computer programs.

MANUFACTURING CONTROL, SUPPLIERS AND END-PRODUCT ASSEMBLY

We have all read numerous articles and attended discussions on the increasing complexity in the business operation. As you can see in the chart, the complexities focus on the Manufacturing Control function and it is here also that we see some of the most impressive systems and data processing progress being recorded.

Manufacturing Control is responsible for accepting end-product requirements received from Sales, relating them to the specifications of the parts which make up the end-products as received from Engineering and translating the result into production and shipping schedules acceptable to supplier and assembly operations as well as to Sales. Manufacturing Control is also responsible for maintaining investments in inventories both at supplier and assembly activities at a level acceptable for financial control purposes. We have here a diversity of interests and a contradiction in objectives among the various activities being served as well as a series of limiting factors at both supplier plants and assembly plants which reveals a set of problems most difficult to define and control.

For purposes of Manufacturing Control, we will assume the receipt of requirements, that is, a sales forecast from Sales for a given number of months in advance. These forecasted end-product requirements must be converted into end-product schedules for each assembly plant. The name given to this work is "Sourcing." It's easy to describe what must be done in general but in actuality assembly plant capacities and costs are all different, shipping costs from assembly plant to various distribution points are different and it may be necessary for some parts to consider the cost of suppliers shipping to assembly plants as well. Theoretically, all the factors I have mentioned and perhaps others could all be incorporated into mathematical formulas and computer programs written to achieve an optimum solution. Ultimately, this or something like it will be done but in the meantime progressive areas of this problem will have to be applied to mathematical and computer control while residual areas will necessarily remain for the time being on a clerical, manual, subjective and suboptimum basis.

The result or "answers" from the sourcing action, that is, the end-product schedules for assembly plants, must now be correlated with the detailed product specifications received from Engineering and releases or parts shipment schedules transmitted to suppliers. We might describe this work as parts scheduling as distinct from sourcing. We can also see that the requirements for an assembly may develop one or more levels of sub-assembly or individual parts requirements. In this area of work computers are used typically throughout the automobile industry. Without computers today's complex product mix and continuing

changes in requirements could hardly be scheduled and controlled regardless of the money spent for clerical work. For comparative purposes we might contemplate attempting to operate a missile or satellite tracking station with an army of accounting machine operators instead of a computer.

Coordination and follow-up with Sales, Suppliers and Assembly Plants is another Manufacturing Control function susceptible to and increasingly applied to computers and other data processing tools. Advance Shipment Notices originated by Suppliers can be forwarded to a control point and through computer programs compared with schedules to prepare exception reports covering only the status of parts which are off schedule. A similar arrangement is possible between assembly plants and the control point, where a wire or radio communication system employing perhaps punched cards, paper tape or magnetic tape transmission may be indicated to reduce the time lag, assure accuracy and maintain control on a daily basis.

Communication, exception reporting and computer programs can yield improved management control in the Manufacturing Control area and can assure production schedules tied in with the latest Sales requirements as well as lower inventory and less loss through obsolescence. Systems work towards these ends will yield long term gains far beyond the dollars and cents savings in clerical and inventory costs which appear on the surface.

SALES AND DISTRIBUTION

Once again we will disregard the clerical aspects of this work and assume that mechanized and computer techniques apply to normal accounting and administrative work as well as the processing of orders, inventory record keeping, etc.

We can see from the chart that Sales is responsible for promoting a product, analyzing actual sales, establishing sales objectives and determining actual end-product requirements for action by Manufacturing Control. Sales must, of course, give recognition to inventories which may be resting in the distribution system before it can submit requirements to Manufacturing.

The estimate of requirements transmitted by Sales to Manufacturing Control is the trigger that sets any business in motion. The compounding of these requirements is the trigger that sets an economy in motion. In our free economy, when the market buys the product, the requirements mobilize business as a whole to productive action. Our economists of a more liberal stamp will tell us that the formula is reversed, that the market withers and dies if the productive process is not somehow sustained and no doubt there is an element of truth in this relationship also.

In concept, if a customer orders a red car with a normal set of other specifications, the car will either be delivered out of dealer inventory or ordered from the assembly plant which presumably has red paint on hand. The basic need, however, is to get the supplier to ship red paint and to apprise Sales of the fact that a red car was sold so its requirements can be modified accordingly. The ability to meet the requirements for a sale was established or lost based on projections made perhaps months ago. Every business, and perhaps especially the automobile business, attempts to provide itself with the ability to meet varying requirements quickly and flexibly. A supply pipeline full of parts which may or may not be used and an end-product inventory which meets the market pattern of a few months ago or last year is the price which often must be paid to place the product required before a fickle market. A slight slowdown in the market absorption of a product doesn't get recognized in production until much later when the over-supply in the pipeline depresses the market further. This in turn results in requirements cut-backs deeper than those warranted by the then current market because it is necessary to correct for the over-supply.

Let us see what contributions management science, including both operations research and new data processing tools, can make to this problem.

Mathematical formulas can be made responsive to the trends in the market before specific over-supplies or shortages force attention. Current detailed end-product inventories can be maintained on computers and these inventories can be recognized in full detail when computer techniques are used in forecasting. Correlation of detailed actual inventory with requirements forecasting is a

basic ingredient in a system designed to control the productive operations of a business in line with the actual market. Communication systems using radio or wire transmission, when tied in with large scale computer records, can assure recognition of and action on the latest information.

I claim no qualifications as an economist but only choose to illustrate the fact that the field of systems control, operations research and computer application which we are discussing will ultimately have a profound affect on the profitability of our individual companies as well as the economy as a whole. The simple contribution is that of taking the time lag, the momentum and the related overrun of goods out of the system. Perhaps the right formulas might even take some of the psychology out of our business planning and forecasting.

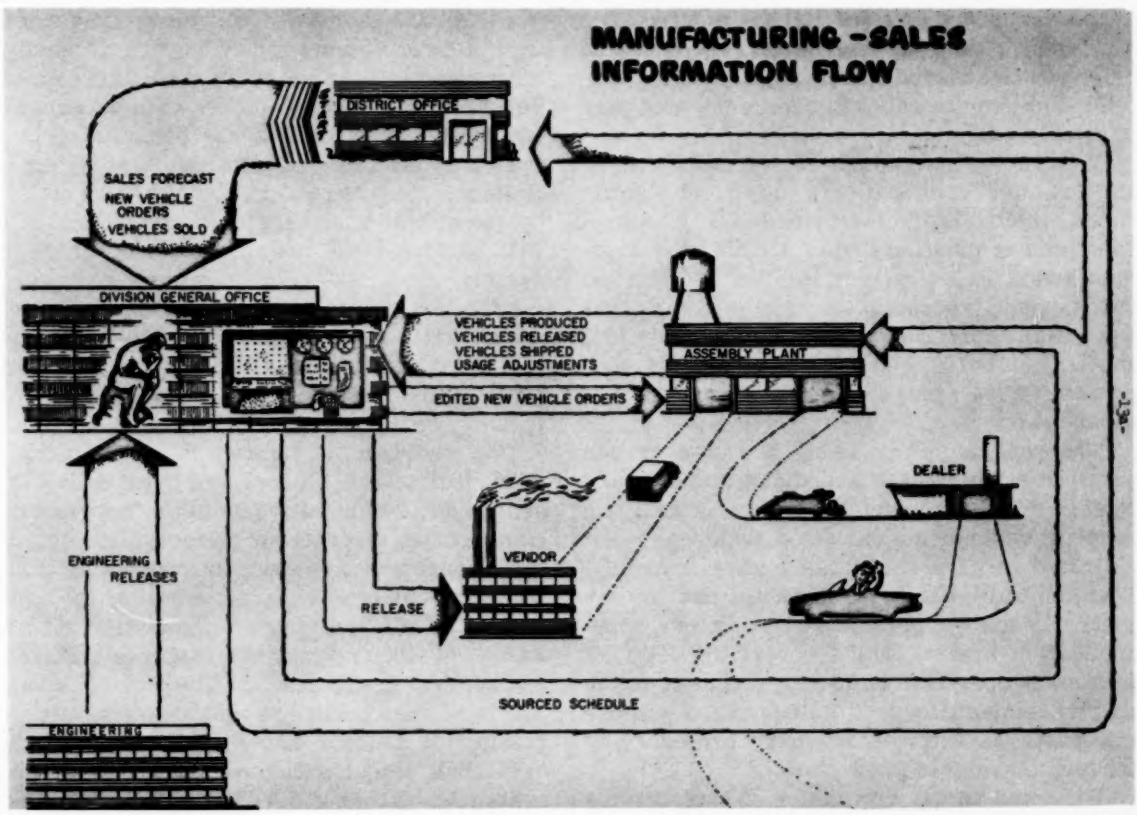
Few will claim that in the general run of business the mathematical sales forecast formulations and inventory control ideas I have discussed will become universal in two or even five years. On the other hand, even the most cynical agree that business forecasting and planning is becoming more and more mechanistic and that new management control techniques and new tools, specifically computers, will stabilize our individual businesses and indirectly the economy as a whole.

A SYSTEMS CHART ILLUSTRATION

By way of illustrating the practical application of new operations research techniques and data processing tools, let us briefly review a chart which shows a possible system for porcessing manufacturing and sales information in the automobile business.

For purposes of this system possibility, we will start with the individual district sales office and assume that sales forecasts for the district are forwarded to the general office periodically and new vehicle orders and reports of vehicles sold, including detailed specidications, are transmitted to the general office daily.

We can see here that the sales forecast



developed at a district level may recognize most effectively special factors affecting sales for that district but probably will be less effective than one prepared centrally where more information and larger scale data processing equipment is available for correlating national economic trends, over-all sales and profit objectives and competitive performance. The number of vehicles required is only a part of the forecast and even if this is generally correct, a significant error in terms of options such as radios, special engines, transmission options and upholstery can create serious losses of potential business or production of vehicles which do not adequately meet the market requirements.

The application of mathematical formulas to sales forecasting is gradual but is a growing area of management science application. It may start on a district level and it may initially involve only the forecasting of options and accessories quantities required to service a more subjective prediction of the total number of vehicles. We can see, however, that use in one area of sales forecasting will open a second area and success in the second area will open a third and a fourth. Growth and progress is assured if each step is taken carefully and results checked before the next step is attempted.

We can see that reports of vehicles ordered and vehicles sold are of a value and significance which justify the installation of a high speed communication system and that the communication is logically in the form of punched cards, paper tape, magnetic tape or other computer intelligible format so that manual effort and time otherwise needed in connection with general office computer input preparation is unnecessary.

The general office using a computer can check assembly plant schedules and forward vehicle orders to assembly plants. Here again wire or radio communication techniques are indicated to save time and assure accuracy. The general office can maintain day by day control of assembly plant operation by a communication system which covers the detail of daily plant operation including, as shown on the chart, vehicles produced, released and shipped and parts inventory necessary for carrying out further vehicle production.

We noted in our discussion of Manufacturing Control that computers are conventionally used to translate sales forecasts into parts requirements released to vendors and that information from Engineering as shown on the chart is a necessary ingredient in these computer programs.

The dealer submits his requirements to the district sales office servicing him, he receives his vehicles from the particular assembly plant or plants which can at lowest cost honor his requirements for various vehicles and the dealer in the final step presents the happy customer with his new car.

THE ROLE OF MANAGEMENT CONTROL

It has been suggested that management control might best be depicted on the chart by picturing the image of management with a set of earphones plugged into the computer and his hands on the computer's control console.

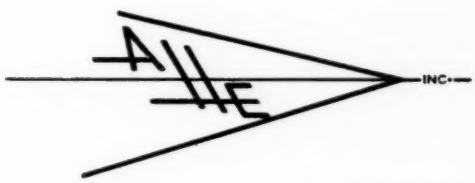
This illustration of the "thinker" shown, however, adequately establishes the point that management is not directly operating a system such as this. It is not, so to speak, "deciding" whether an assembly plant can or cannot produce a given volume of new orders or whether more station wagons with green trim should be put in the schedule or whether a parts release should be for 2,000 or 2,500 pieces. Most aspects of these past, and to some extent present, management responsibilities will be by-passed and management responsibilities will be to set the specifications by which the system operates.

This new type of management control which, as we have said, is only possible if serviced by new techniques, new tools and new ideas poses both a problem and an opportunity for industry today.

The problem can be seen if we admit that a good deal of the balance and perspective in a successful business today is the net result of experienced, discrete and reasonably objective top management resolving the conflicting pressures and objectives characteristic of the various areas of a company's organization such as Sales, Manufacturing, Engineering, Finance and other. It will take a full quota of imagination, resourcefulness and diligent work to retain this balance and perspective in the increasingly mechanistic and impersonal control systems now being developed and installed.

There is danger that one or another interested group or one or another philosophy of operation will destroy the built in balance generally characteristic of present operation.

The opportunity which confronts business is well beyond the opportunity for greater profit or competitive advantage through being first in the parade of progress. As more and more of the day to day problems confronting the best minds and most capable talent in management today are proceduralized and standardized, that same talent can move from operating to planning and from tactical to strategic decision making. It has been stated that the function of management is to make decisions within the limitations of inadequate time, incomplete or out-of-date facts and limited alternatives. Continued progress in understanding and applying the tools and techniques which we have discussed can remove from management a host of operating problems which today steal management's time, they can provide complete and up to date facts on any defined area of information and they can develop analytical techniques for evaluating alternatives to an extent never possible in the past. Full development of the potential inherent in computers and the related mathematical and data processing tools now available may well be one of the greatest opportunities for growth and progress confronting American business today.



BUDGETING TECHNIQUES

by **STANLEY T. WEBER**
Director of Finance Staff
GENERAL MOTORS CORPORATION

Michigan State College - Class of 1942 - School of Business Administration.

Started business career with J. C. Penny Company at Lansing, Michigan.

Critical war situation led to war employment at the Oldsmobile Division of General Motors.

Performed numerous assignments in cost work and subsequently appointed supervisor of Cost and Factory Accounting at Oldsmobile.

In 1949 was transferred to the Detroit Central Office Financial Staff of General Motors Corporation as a financial analyst specializing in cost and budget control work.

Subsequently appointed supervisor of Analytical Accounting and has also supervised Property Accounting and Manufacturing Expense Control Departments in the General Motors Cost Analysis and Operations Analysis Sections.

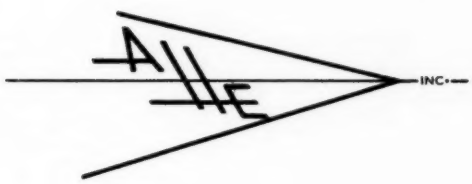
Became Assistant Director of the Operations Analysis Section in 1956 and Director in 1958. The Operations Analysis Section is responsible for budget control, pricing, and financial analysis for General Motors Corporation.

THE BUDGET AS AN OPERATING CONTROL

By S. T. WEBER

Director, Finance Staff, General Motors Corporation

A GENERAL review of definition, types and applications of budgets in industry is the background for discussion. This is followed by development of a budget for a specific product and use of this budget as an operating control.



LABOR NEGOTIATIONS - UNIONS AND WAGE INCENTIVES

by **E. F. SCOUTTEN**
Vice President in Charge of Personnel
MAYTAG COMPANY

E. F. Scoutten, Vice-President, Personnel, for the Maytag company, joined the organization in March, 1952. He formerly was employed with the Houdaille-Hershey corporation at Detroit, where he was assistant to the director of industrial relations.

At Maytag, Mr. Scoutten is responsible for all personnel functions, including labor relations, union contract negotiations, wage and salary administration, pensions and retirement plans, insurance programs, plant protection, safety, employment, training programs and the medical program for all employees.

A native of Ohio, Mr. Scoutten was graduated from high school at Hudson, Ohio, and received his bachelor of science degree from Kent State University, Kent, Ohio. He received his M.A. degree in 1937 and Ph.D. degree in 1942, both at Ohio State University, Columbus.

On leaving Kent State, Mr. Scoutten was engaged in education work in the public school system in Lisbon, Worthington and Columbus, Ohio, before going to work for the Pennsylvania Ordnance works, Williamsport, Pa., as training director. He later was associated with the Naugatuck chemical division, U. S. Rubber company, Naugatuck, Conn., as supervisor of production control, and the synthetic rubber division of U. S. Rubber at Charleston, W. Va., as industrial relations supervisor.

Mr. Scoutten returned to the education field at the University of Rochester, Rochester, N. Y., for a year during which time he moderated a national weekly radio forum known as "Junior Town Meeting of the Air."

He then returned to Naugatuck to serve as assistant industrial relations manager there before accepting a position with Houdaille-Hershey corporation in May, 1949, as assistant to the director of industrial relations for Houdaille-Hershey at Detroit.

LABOR NEGOTIATIONS - UNIONS AND WAGE INCENTIVES

By E. F. SCOUTTEN

Vice-President, Personnel, The Maytag Company - Newton, Iowa

(Based on Material Prepared By G. O. Fairweather, Member of The Firm of Seyfarth, Shaw, Fairweather & Geraldson - Chicago, Illinois)

IN PLANTS where employees work under incentives, the establishment of incentive standards is the activity around which much of the day-to-day labor relations problems revolve. This is perfectly natural. The incentive standards determine the compensation which the employee receives and the effort he must put forth. Employees naturally desire to receive more pay for less work, which is an understandable human motivation. Unfortunately, however, we find the labor unions will cater to this natural desire, and charge that incentive systems are designed to "get more work" for less pay and hence are "speed ups" unfair to the employee.

Merely to note that type of expression by a labor leader, let me read what Walter Reuther had to say: "The terrible pressure of 'speed up' originally organized the UAW-CIO. Now, production rates are subject to union scrutiny. Recently, the union has won the right to examine the company's time study work sheets. The right of the union to strike over 'speed up' grievances has been established at the time contracts are negotiated. Continuous progress has been made in the fight against 'speed up', but to maintain what has been won, and to continue to fight against it, the steward and the committeemen in the shop must be trained and alert, and must be educated to the effective use of the grievance machinery."

Underlying Mr. Reuther's comments is an attack theme which, when repeated over and over, poisons employees' attitudes toward incentive systems, and which must be recorded by all who are charged with the job of maintaining sound incentive practices in a plant.

The maintenance of a sound incentive system is often essential to the company's survival. In many industries, the competitive advantage of one company over the others is only found in the effectiveness of its incentive program. If such a company's incentive program gets out of gear, costs will "go to pieces", and the company starts to sink competitively.

From the viewpoint of our national economy, the maintenance of sound incentive systems is equally important. If the attack by labor unions develops pressures which, when brought to bear against incentive programs, causes them to break down, the productivity per hour of our industrial system will go down. Stated another way, this is the same thing as saying that the maintenance of good incentive systems is one of the essentials to the maintenance of a high national standard of living.

All thoughtful managements who operate plants with incentive systems know all this, and attempt to adopt for themselves a plan to protect their system from the injury which could result if those who attack the system can turn their attacks into destructive restrictions. Let us look at some of these efforts by managements and attempt to appraise their effectiveness.

PLAN 1: RESERVING TO MANAGEMENT THE FINAL DETERMINATION OVER INCENTIVE STANDARDS

One position that managements often take can be stated something like this:

"We establish the incentive standards. The Union can't promise us extra effort upon the part of each individual employee. The incentive standard provides an earnings opportunity over and above the wage structure which we

negotiated with the union. Hence, incentive standards are something personal between the company and the individual employee. If the individual employee doesn't believe the standard is fair, he, or the union, can file a grievance on his behalf, but such grievance cannot go to arbitration. Since we, the management, are providing this 'extra' earnings, we should have the final say."

The union representatives say in turn:

"If that is the position you take, we want the right to strike if you don't establish an incentive rate to our satisfaction."

Management might then say quietly to itself:

"The employees won't strike over every incentive standard which we establish. If we can keep the final say, we will, in fact, keep control of our incentive system."

The unions, at least many of them, don't disagree with such a view. Many unions don't believe incentive disputes should be submitted to arbitration. Such unions, however, want to retain a specific right to strike over such disputes. Particularly is such a position typical of the UAW-CIO. The UAW's position is used to illustrate union attitudes toward incentive systems and the handling of incentive disputes, because when it comes to incentive problems, it is likely the most sophisticated large union, as it represents employees in many metal fabricating plants where incentives of all types are used extensively.

However, the union's basic reasons for not desiring to arbitrate incentive standards are somewhat different from those of the management. First, the union wants to bargain over incentive rates. If a dispute can go to arbitration, a pattern decision might be established which might limit its ability to "bargain up" incentive standards. Secondly, the reservation of the right to strike over incentive standards is a "loop hole" in the long five-year labor agreements which the UAW-CIO entered into with many companies. A dispute over an incentive standard can always be generated if it becomes necessary to strike, so as to "bail out" from such an agreement. Thirdly, retaining the right to bargain and, if need be, to strike over incentive rate disputes permits more "gains" to be made, the union believes, and gains are needed to maintain a cohesive interest in the union, especially during the period of these long-term agreements.

The difficulty with this "retention of final control" approach to the protection of an incentive system is that it surrounds the incentive system with an atmosphere of contest. "The employee must 'take it' or strike" position, which may not be expressed, but is still the underlying fact, confronts the employees with a dilemma. They feel trapped. The creation of such a dilemma surrounds the system with emotional tensions which are not conducive to the development of the truly correct attitudes toward incentive compensation. These tensions can build up and can become very deep seated. The Union can then stimulate these tensions and beliefs simply by using slogan phrases such as "speed up", "chiseling", "man-killing rates", and so forth, with the result that the attitude of the employees toward the incentive system disintegrates even more.

Under such a plan, the company might stay in the "driver's seat" for a period of time. However, when collective bargaining time rolls around again, the union will be in a better position to build up a strike pressure and bring it to bear at the conference table, to obtain restrictive contract clauses. If the management concedes the restrictions, the battle to protect the incentive system will be over. The refusal to submit incentive disputes to arbitration - a position adopted to keep the incentive ship afloat - may cause the frustrations that build into destructive pressures which, when released, may ultimately cause the incentive ship to sink.

PLAN 2: A WILLINGNESS TO ARBITRATE INCENTIVE DISPUTES MAY ACTUALLY PROTECT THE INCENTIVE SYSTEM

We have, as the other alternative, the idea that we should submit incentive disputes to arbitration. When a company is willing to do this, it can counteract the sloganized attacks of "speed up" and "chiseling" by replying: "Let's find out if what you say is true; we will submit the question in dispute to an impartial outsider."

However, to the suggestion that incentive disputes be arbitrated, many managements will reply: "The whole idea seems alright - but few of the recognized arbitrators are industrial engineers, and the union wouldn't agree to arbitrate such disputes before an

industrial engineer from a management consulting firm. Since we couldn't find an industrial engineer who was mutually acceptable, we don't think we should submit our incentive disputes to arbitration."

Such belief seems reasonable on the surface, but a fundamental and deep-seated problem is revealed by such a position. If a management believes that it cannot convince an impartial arbitrator of the fairness of an incentive standard, because he is not an industrial engineer, it is admitting that it can't convince just ordinary, fair-minded people that an incentive standard is fair. If that is true, how can management convince its employees and the union leaders, who are not trained engineers, that an incentive standard or its incentive system is fair? That really puts the question.

The Proof Of The Fairness Of An Incentive Rate

The question is does management have techniques which are good enough to convince all comers that its incentive system is fair, and that an individual incentive standard has been correctly established? If management has those techniques, then it should be in a position to prove that it has been fair, and should be willing to agree to submit incentive disputes to lay arbitrators - lay in the sense that they are not industrial engineers.

Companies that have taken this step - have agreed to submit incentive disputes to arbitration - which they have done after some soul-searching and worry, have immediately set about to develop the methods of proof which would be needed to establish the fairness of an incentive standard in an arbitration case. They have also re-inspected much more critically the provisions of their labor agreements. As their techniques improve and the labor agreement provisions become more sound in theory and clearer in language, they find that their ability to "sell" incentive standards to employees and to union leaders increases, and, thereupon, the need to resort to arbitration to resolve incentive disputes actually diminishes.

Our task, therefore, is to examine some of the provisions of labor agreements concerning incentive rate establishment, not so much in detail but in concept, and then to consider some of the methods of proof that can be used if a dispute over an incentive standard reaches arbitration.

The "Standard Of Fairness" In A Labor Agreement

The first and most important provision or provisions of the labor agreement which are involved in the incentive rate establishment problem, and the subsequent proof of the fairness of a rate if a dispute arises, can be called the "standard of fairness". This term is applied to the provision, or provisions, of the labor agreement against which the individual rate in dispute is compared, to determine whether the rate is "fair" or not. "Standards of fairness" provisions which are found in labor agreements fall generally into three types.

Type 1: The Specification Of The Methods To Be Followed in Establishing A Rate

The first general type of "standard of fairness" found in labor agreements consists of provisions which specify the methods to be followed in establishing the incentive rate. The theory behind such provisions is that if the management has followed the specified method step by step when it established the disputed rate, then the resulting rate must necessarily be fair. Such an approach to contractual provisions to determine whether a rate is fair or not should be rejected for two very basic reasons:

First, the detailed procedures to be followed by the industrial engineering or methods and rates department should not be projected into the collective bargaining arena. The procedures and techniques of establishing incentive rates are technical matters, and may vary as the type of task being studied varies. Which procedure or technique is proper is a matter for the trained personnel in the Methods and Rates Department. No other department of the Company - Accounting, Payroll, or Production Engineering - would permit their procedures and methods to be "chewed over" and defined, limited, or distorted at the

collective bargaining table. The ability of a staff department to discharge its responsibilities properly and efficiently varies directly with its ability to use the best and most modern procedures, and to improve those procedures without interference by untrained outsiders. If the methods and procedures to be used by the expert staff are fixed by others, such a fundamental principle of organization is violated. You cannot place the responsibility for good performance upon a Methods and Rates Department and permit persons who do not have the responsibility for performance to tie its hands by specifying in a labor agreement the methods and procedures it must follow.

Secondly, the specification of the methods of rate establishment in the labor agreement actually multiplies disputes, and a mere comparison of methods used with methods specified may have little to do with the actual fairness of the rate in dispute. To illustrate this, let us examine some actual provisions of labor agreements which have resulted from collective bargaining that "wander" into the methods specifications area:

First, "The maximum of a 60-minute study or 20 cycles, whichever is greater, shall be made in any time study." This sounds reasonable, on first impression, because the measurement of a substantial number of cycles generally means greater accuracy. However, such a provision will permit the union steward to thumb through piles of work sheets seeking "illegal" rates. If, for example, he found one study based on 18 cycles, he could declare it "illegal". This proves the company "cheated" and the rate must then be cancelled. However, if the rate established on only 18 cycles actually provided an adequate earnings opportunity, the cancellation of the rate benefits no one, and merely increases dissatisfaction and contention. Such a provision concerning method has nothing to do with the inherent fairness of the rate. Incidentally, and as a footnote on that particular type of provision, a steward once declared a price illegal because a sufficient number of cycles had not been observed, and after the incentive rate was cancelled, the company established another one which was considerably tighter. Another ruckus arose because the union steward was politically embarrassed.

Second, "All time studies shall be taken by the continuous watch-reading method." An effort in the labor agreement to control how a watch is to be read is an effort to control the leveling process. Such control on the leveling process creates inaccuracies and loose rates. Furthermore, such a provision establishes a sound reason for employees to slow down their performance while being observed in the hope that the performance time which is thereby recorded by a continuous watch-reading method will produce a loose rate.

Third, "The worker who is to be time-studied and the union steward shall be advised one-half hour before the time study takes place." Union spokesmen argue that such a provision is wise because, without advance notice, an employee is not equipped psychologically for the time study. However, a local union president, late one night and in a boastful moment, admitted that the real reason his union wanted such a clause was to allow the employee time to dull his cutting tools, to reduce the feeds and speeds, and to rearrange the work station, in the hope that a loose standard would be issued if the time study man did not "catch" all of the inefficiencies which had been introducted.

Fourth, "If any observation time is not used in the calculation of a time study, a clear explanation of why it was not used shall be noted on the observation sheet and this means no strike-outs." Obviously, the elimination of each false motion or period of wasted time becomes a separate dispute, even if an accurate rate could only be established by the elimination of this time.

Fifth, "Observed time may or may not be leveled, as the case may be. However, no time which is rated, either in whole or in part, lower than 85% shall be used as the basis for an incentive standard." A time study observer, if he is observing very bad performance, possibly should "walk away from the study". This undoubtedly is good incentive procedure. The closer the employee is working to 100% performance, the more accurate the study will be, because the need for substantial adjustment of the observed time is less. However, with such a provision in a labor agreement, what happens? Employees soon learn that if they hold their performance down to what they think is 80% performance, they might get a 5% break because the time study observer will not

"walk away", but out of sheer frustration will record the poor performance and level the performance at 85%. A loose standard will be the result. Loose standards breed inequity claims, and then "the whole thing goes to pieces".

Sixth, some contracts even say, *"When the time study man leaves the floor, he must give the following things in writing to the worker: The exact total time period in which the study took place; the number of pieces produced during the time study; the leveling factors; and the allowances granted in minutes."* Such a clause has the effect of forcing an immediate judgment concerning the leveling to be applied to the operator's performance. The industrial engineer is given no opportunity for reflection, consultation, or to examine comparative data. Such a rule in a contract can have only one purpose - the forcing of quick judgment which will be inaccurate.

If you trace the reason for management's willingness to incorporate most of these methods specification provisions into labor agreements, you will find that, historically, they were taken from some provision in a company time study manual. Management negotiators, somewhat innocently, have agreed to incorporate into labor agreements descriptions of procedural methods lifted from the time study manuals prepared by the Methods and Rates Department personnel, in the belief that such personnel would not be hindered thereby, nor can they object. However, labor agreements and time study manuals are different things; an expression in a manual may cause an entirely different and unexpected result when it is incorporated in a labor agreement.

What is even more serious about method specifications in labor agreements is that it ties the company down to one method, only. With varying types of production in a plant, the Methods and Rates Department personnel should be free to use the appropriate method designed for the particular type of task being measured.

Thus, it can be seen that the negotiation over methods and procedures can entrap the company completely, and even if the methods are specified in the agreement, a real "standard of fairness" is not obtained.

Type 2: The Earnings Opportunity Standard of Fairness

The second type of "standard of fairness" provision found in labor agreements is based upon the theory that the "proof of an incentive standard is in the eating"; or, in other words, that a true standard of fairness should establish the "earnings opportunity" above the negotiated rate structure which should be provided by an incentive rate. Such a standard of fairness reflects the belief that the real thing one should talk about in collective bargaining is "wages", and not the "methods" of developing those wages.

Such a standard involves simply an agreement with the union on a level of earnings opportunity which should be provided for an employee willing to work with incentive effort if a particular incentive standard is to be considered "fair" or, stated in the reverse, it involves an agreement that if an incentive standard does not produce for such an employee an earnings opportunity at least equal to that standard, it shall be considered "unfair".

This type of "standard of fairness" provision relates incentive earnings opportunities to the negotiated base rate structure, by relating the earnings opportunity to the base rate of the particular employee's classification. Thus, it anchors the incentive system to the negotiated structure, and such an anchor generally proves to be extremely valuable to the Company.

Many incentive engineers, in establishing incentive rates in a certain department of a plant, find that the employees have an earnings expectancy or target rate which must be met, or the incentive rate will not be acceptable to the employees. The expectancy or target rate may be different in the different departments of the same plant. However, if the relationship between the base rate structure and the earnings opportunity of incentive standards has been established in the labor agreement, individualized departmental or group expectancies tend to break down. The industrial engineer has a concrete relationship to work with, and is better able to maintain a consistent earnings opportunity throughout the plant. Without it, inconsistent earnings expectancies,

which, even though not expressed in writing, are very real, will grow up in the various departments. Hence it is sound from a negotiation point of view, as well as an administration standpoint, to key the earnings opportunities of incentive standards back to the basic negotiated rate structure.

Furthermore, this view is consistent with the idea that incentives are designed to compensate employees for extra effort, and that the compensation for the skills employed on the job is in the base rate. This is an important concept. It is generally known, but usually forgotten.

The Construction Of An "Earnings Opportunity Standard Of Fairness"

Let us assume that a particular management adopts for itself, as a matter of policy, the view that an employee working with full incentive effort will put forth about 25% more effort than the same employee would put forth when working on a day work basis. This management then concludes that it is correct to pay such an employee 25% more pay if he puts forth full incentive effort. Such an assumption covering the extra effort that will be put forth under full incentive stimulation is a normal assumption, and has been substantially validated statistically.

In such a company, we would then establish a line on a chart 25% above the base rates of the various classifications, and the objective of the management would be accomplished if the average incentive opportunities for employees in the various classifications, when plotted on this chart, fell on the "Company Policy Objective" line, 25% above the base rates.

However, the formula is not quite this simple. We cannot express a 25% percentage relationship between earnings opportunity and base rate, even if it is our actual objective as a commitment in the labor agreement, because an expression would soon get the company into trouble. It would have these results:

First, the Methods and Rates Department personnel, if they used only a 25% incentive factor when the incentive rates are being established, would never be sure whether they had properly discharged the obligation assumed in the labor agreement. Individual incentive rates cannot be established that accurately.

Secondly, the employees might commence to hold back their production on all new incentive rates, and claim an increase in the incentive standard was required on the grounds that the 25% earnings expectancy called for by the labor agreement had not been provided. Due to the uncertainty introduced by the possibility of error, the slowdowns and contentions that might surround each new rate, the Methods and Rates Department will be under a pressure to use a higher incentive factor - for example, a 30% factor - in the establishment of the rates to develop for themselves a "margin of safety", so that it can be demonstrated that each standard the Department establishes is consistent with the commitment in the labor agreement. The use of a higher incentive standard, i.e., 30%, either informally or formally, will, of course, have the effect of raising costs above the level contemplated when the 25% policy was adopted.

We must, therefore, at the time the "standard of fairness" is constructed and incorporated into the labor agreement, recognize that industrial engineers are actually human beings, and, as human beings, cannot establish incentive rates with mathematical precision. If we assume that we can expect from industrial engineers, individual incentive standards which are accurate within 5% plus or minus, the Methods and Rate Department would be discharging its obligation properly if the average earnings opportunity is 25%, but individual incentive standards would be established properly if some of them provided an earnings opportunity of only 20% while others provided an earnings opportunity of as high as 30%.

When the actual ability of the Methods and Rates Department to establish incentive standards under a 25% company policy is determined, we find that the "Standard Of Fairness" should recognize that individual standards are proper if the earnings opportunity falls above a minimum level of 20%. Even when judgment leveling is done most accurately, as many as 18 out of every 100 standards will have earnings opportunities which fall below 20% when initially established. Therefore, the labor agreement should not express as a commitment, the 25%

policy, but, rather, it should express the percentage level below which a rate should be considered unfair. The highest that this level should be is 20% above the base rates of the particular classifications. It is this percentage level that may be considered the "minimum of the range of fairness".

However, if the negotiating parties are completely realistic about the problems involved in incentive rate establishment, they should weigh into the equation the fact that employees do slow down. Union representatives are not going to argue very long or very hard about this fact, because they know it is true. If this problem is squarely faced and fully discussed with the union leaders, it is possible to establish the minimum of the "band of fairness" somewhat lower than 20% above the base rate, possibly at a point 18% or even 15% above the base rates of the classification.

By establishing the minimum for the band of fairness, the parties are making an agreement that if an individual incentive standard is established by the management which does not have an earnings opportunity of 15% or 18% above the base rate, the incentive rate is not fair. Such an agreement is consistent with a policy that says that the average earnings opportunity should be 25% above the base rates, but recognizes two facts - that industrial engineers will establish standards which produce earnings on both sides of the policy target, and that employees will slow down if the contract standard does not contain an adequate margin of safety. If a sound "standard of fairness" is to be incorporated into an agreement, it must recognize the actual facts surrounding the establishment of incentive rates. The only real bargaining area that should be involved is the establishment of the number of percentage points below 20% which is the maximum point that can be established, assuming that plus and minus 5% is the maximum degree of accuracy that can be expected from the industrial engineers. As the extent that this minimum point is fixed below 20% is increased, the margin of safety that is being provided the Methods and Rates Department is increased.

When you finally come to write up the provision for the labor agreement, the expression would be something like this:

> "A normal operator working with incentive effort should have an opportunity to earn at least 15% (or 18%) over his base rate."

Such an expression merely means that if an individual incentive rate does not provide such an earnings opportunity for incentive effort, the parties have agreed that such rate is "unfair", and has been established in a manner inconsistent with the commitment expressed in the labor agreement.

Generally, industrial engineers have been remiss in that they have not insisted that the management representatives who handle the collective bargaining establish, in the labor agreement, standards which are realistically consistent with the job the industrial engineers can perform, so that they can discharge their duties with a minimum of contention. Unfortunately, many labor agreements impose upon the industrial engineers a task which they cannot discharge properly and, under such agreements, the industrial engineers "catch the blame" for the resulting breakdown of the incentive system and the inevitable increase in costs.

Split Systems Have Advantages As Well As Disadvantages

We have been considering the establishment of a "standard of fairness" for a company with a policy which directs the Methods and Rates Department to provide an average of 25% earnings opportunity when an employee is working with incentive effort. Should such a policy provide the same opportunity when a machine operator is not putting forth incentive effort, but is standing by watching his machine operate? We should not pass on without mentioning the "split systems", as I call them for lack of a better name, which provide different earnings opportunities for the "manual portions and "machine" portions of an incentive task.

Where there is a great deal of machine work performed in a plant, it is generally believed, as a matter of policy, that it is not sound to pay full incentive compensation to the employee while he is idle - standing by watching the machine work. Incentive pay is

the payment for extra effort expended, and to pay full incentive pay during periods when no effort is expended is inconsistent with that basic concept. Companies which adopt this view often provide a higher incentive factor for the "manual elements" of the task (equal to 25%) and a lower incentive factor for the "machine observation elements" (equal to only 10%). Some systems pay incentive only for manual elements, and nothing for delay or machine time.

Split systems, consistent with good incentive theory, have distinct advantages. They permit an increase in the incentive compensation automatically when the employee is asked to perform additional manual activity during the period of machine operation.

For example, let us assume that the duties of a lathe operator are changed so that, during the machine cycle time of the lathe he operates, he is asked to turn around and chuck a piece into a second lathe placed immediately behind him. Under such a change of job duties, the actual manual work which he performs would be doubled. Under a "split system", his incentive earnings opportunity would automatically be increased.

As another example, let us assume that there is a bottleneck in the group, and there is idle time below the bottleneck. If the bottleneck is changed and the manual activity of the employees in the group below the bottleneck is increased, the compensation of the group would automatically go up under a "split system".

Such systems make it possible to explain to employees, the fairness of their incentive compensation when such job duty changes occur. It can be demonstrated that their earnings opportunity increases as the amount of manual work an employee is asked to perform increases.

Union representatives and employees don't like "split systems". They say, "Why should the employee tied to the machine be penalized? It isn't his fault. He should have the same earnings opportunity as the other fellows." For this reason, such systems can create dissatisfaction. Many companies, therefore, have moved to the single system, - that is, the use of a constant incentive opportunity factor which is applied both to the manual elements and the machine elements of the task. Some managements have done this for thoughtful reasons. They realize that if they move toward more and more mechanization, they will get a resistance to technological change if incentive earnings keep going down as the new machines, with longer cycles, are introduced. If a single earnings opportunity factor is used for both manual and machine observation elements, a second very important provision must be introduced into the labor agreement. This is the provision which establishes the company's right to require manual activity during machine observation time without an increase in earnings. This right must be established after complete bargaining at the collective bargaining table. If it is not bargained out and set forth clearly in the labor agreement with the union, the company will run the risk of getting caught in the emotional claim of "speed up" when the employee is asked to perform manual activity during the machine observation time. It is true that when such changes occur, an employee is being asked to do more manual work. Without such a clause in the labor agreement, it is difficult to demonstrate to each and every employee the fairness of the incentive standard provided for the new task. The clause in the labor agreement helps explain that since you were paying the employee as if he were expending full effort during the machine observation periods when no effort was expended, you now have a right to ask him to perform work during such periods without increased compensation.

The following provision is taken from a labor agreement which covers the introduction of manual activity during machine observation time, and also reflects the understandings reached when a company changed from a "split system" to a " single incentive factor" system:

> "The labor standard established by the Methods and Rates Department shall provide a normal employee, working with incentive effort, an earnings opportunity of at least 18% above the base rate of the employee's classification. (It is expressly understood that the change in the machine observation time minimum earnings opportunity factor from 10% to 18% effective as of the date of this agreement shall apply to only new or changed standards established after the effective

date of this agreement.) Where changes in job procedures require manual activity to be performed during machine observation time, it is understood that such activity can be added without establishing a labor standard which requires fewer pieces per hour than was required by the prior standard, until the machine observation time of the prior standard is used up."

The latter part of this provision permits the management to say to an employee, "If you were doing Job A, and we come along and give you Job A-1, you won't get any more money until the active work you are now asked to perform catches up with the active work we were actually paying you for when you performed Job A."

There Should Be A Trial Period Before The Normal Grievance

Previously, we have considered the basic provisions of the labor agreement based on the view that an incentive standard should provide at least a minimum earnings opportunity above the base rate for incentive effort. The Industrial Engineering Department is thereby given a policy objective which it must follow and a standard of fairness which can be applied, to find out whether, with respect to an individual standard, that Department met its obligation.

Under such an approach, the employee or employees should be required to try out the standard by working on the job. The amount of time that should be required for the trial period will vary. Some plants characteristically have short production runs, where others have long ones. Trial periods of substantial duration are more feasible in the latter type of plant. However, the real reason for a trial period is to delay the projection of a dispute into the formal grievance procedure. If the standard is honestly set to provide an earnings opportunity above the minimum figure established in the labor agreement, many times a slight delay will actually cure the dispute. Where standards are carefully established, the employees soon learn that the standards will produce the earnings if they want to go to work and some delay, due to a trial period, makes slowdowns to get an undeserved adjustment more expensive for the employee.

This does not mean that oral complaints about a standard during the formal trial period should not cause the Methods and Rates Department to make a recheck for possible error very promptly. Sometimes, a four-hour study, or even an eight-hour study of a standard which is in informal dispute will cause the employee to "go over" the minimum established in the agreement. Such an event may show the futility of a formal grievance, and the matter is settled.

The Leveling Problem And The Arbitration Step

Let us now consider the problems which arise when an incentive dispute goes to arbitration. Such a dispute will rarely involve machine cycle times, as they can be generally mathematically determined. Such disputes, therefore, will generally involve the time required to perform the manual elements of the task, because the time recorded to actually perform the manual elements must be leveled to the time that a "normal" man would require to perform such manual tasks, working either at day work (low task) of incentive (high task) pace. The dispute will revolve around the accuracy of the leveling of the operator performance time.

When the typical observation or judgment leveling has been used to level operator performance, the arbitrator will be asked to look through the eyes of a time study observer at an employee the arbitrator never say, to determine whether the work pace was correct. The arbitrator is being asked to make a difficult decision. If the union also has the right to have one of its observers observe the employee performing the job, the dispute will involve the variation between the judgments of the two observers. Under such circumstances, the arbitrator's problem is made even more difficult. There are ways to demonstrate in arbitration the accuracy of judgment leveling. However, since we cannot consider all of the proof methods here, let us consider in some detail one method. This is the use of predetermined time values to prove the accuracy of a leveling of operator performance. This

method will assume more and more importance in arbitration.

Use Of Predetermined Times In A Leveling Dispute

There are two rather well-known predetermined time systems: Methods Time Measurement and Work Factor:

MTM is generally considered a "low task" system. That means that the resulting time to perform the manual elements of the task represents the time a normal employee would require to perform the task at day work effort. You must assume that an employee will increase his effort above 100% by 20% to 25% as a result of incentive stimulation. In arbitration, a low task standard is more difficult to use, because it involves this assumption--that an employee can perform the task in 25% less time than the standard time indicates. Some companies, therefore, convert MTM results to a high task standard by multiplying the TMS's by .0048 rather than the typical .0062.

Work Factor produces a high task standard to which you add your incentive factor. Then you can point to the 25% incentive earnings opportunity factor which is added to the normal time in the calculation and say,

> "Mr. Arbitrator, there it is. We added 25% to the time and, as you will notice, that fully satisfies the contractual 'standard of fairness' which provides that a standard will be unfair only if it does not provide 18% for incentive effort."

If the time required to perform the manual portions of a particular task is computed under a predetermined time system, and the result is submitted to the arbitrator, he will then have before him objective information upon which he can rely to make his determination concerning the accuracy of the judgment levelings which are in dispute.

The Possible Judgment Errors In Applying Predetermined Times Can Be Resolved

An argument can arise concerning the application of a predetermined time value to a particular motion. Such an argument might be the question of whether the task requires a piece to be moved to an "exact location" or to an "approximate location". Let us assume that a dispute over which of these two types of move are involved arises, and that the arbitrator makes what the management believes to be a mistake in his determination, after having examined the job and having the alternate predetermined time applications fully explained. Since the arbitrator will be working with various alternative applications concerning which reasonable men might differ, he could select the one the company thought was wrong, but such a determination will usually change the standard a very small amount. If only such a change could be hoped for, the union would not be encouraged to submit many cases to arbitration.

Furthermore, the dispute would resemble quite closely a dispute involving the slotting of a given type of work into one of two described job classifications. The arbitrator is asked, after examining the work of the job classification, its skills, responsibilities, fatigue factors, etc., and hearing the contentions of the parties, whether it should be classified as the union contends into Labor Grade 11, or remain where the company has classified it in Labor Grade 10.

There is an established principle in arbitration, reflecting properly the management function, to the effect that if management has the initial right to make a determination, the arbitrator should not substitute his judgment, unless he finds that the company's initial judgment was applied in an arbitrary manner. Arbitrator Wardlaw stated this rule as follows:

> "It is not the function of the arbitrator to substitute his judgment for that of the party primarily having the right to exercise it in the first instance, unless there is a clear showing that the action was taken in an arbitrary manner or not in accord with the intent and meaning of the agreement."

Therefore, even if reasonable men could differ about the slotting of a motion into the predetermined time value chart, the determination of the management should not be disturbed

under this rule unless it is shown to be arbitrary.

Incidentally, in this connection, professors of Industrial Engineering at the various universities can be extremely helpful to managements and to arbitrators. In fact, they carry a great responsibility in this effort to protect good incentive systems, by assisting as expert witnesses in arbitration cases to explain to arbitrators the development background and accuracy of these newer techniques. Acting as expert witnesses, such men can analyze the application of a predetermined times method to a given job, and thereby minimize the doubts which might otherwise exist concerning the system and the particular application.

A Use Of Predetermined Times As A Proof Procedure Produces Other Benefits

There are other values to be derived from the use of predetermined times, even when their use is limited to proof of the accuracy of leveling which should be noted. When the study of these techniques progresses, two things start to happen: *First,* there is a renewed concentration on better description of the methods employed on an incentive task. It is always difficult to handle an incentive dispute in arbitration if the person presenting the case can't determine just what task the standard was intended to cover because of inadequacy in the description of the method. If that person can't be sure, how can he "sell" the arbitrator? You can't use predetermined times even as a proof method, unless the motion pattern employed is carefully described. *Second,* the use of these techniques increases the concentration on finding the best motion pattern or method of performing the task. It is the timing of false or inefficient motion patterns in conjunction with inadequate methods description that causes most of our difficult grievances. When these procedures are used, emphasis will be put on work simplification procedures, and the operators will be instructed to follow the "best" motion pattern. This all adds up to better incentive administration.

Improved incentive work, which comes from good method analysis and the training of employees to use the "best" motion patterns, may cause a psychological problem we should not ignore. Unions make the claim that such procedures make the working man into a machine; that the last of his individuality disappears when you tell him, "You must move your body just this way when you perform this task." However, if a management can find a way of reducing the human effort involved in performing a task, the effect may be psychologically bad, but the result is socially good. Even the UAW says this: In the long-term contracts, you will typically find this language:

> "The Annual improvement factor provided in this section recognizes a continuing improvement in the standard of living of employees which depends on technological progress, better tools, methods, processes, skills and cooperative attitudes on the part of all parties in such progress. It further recognizes the principle that to produce more with the same amount of human effort is a sound and social objective . . . ."

The Union's Attitude Toward Predetermined Times

However, this general statement endorsing ways to reduce the expenditure of human effort by improving methods does not cause the UAW to endorse predetermined times systems. Here is what Walter Reuther said in a memorandum to the District Directors on December 8, 1949:

> "A new scientific management system, known as Methods Time Measurement is receiving wide publicity in management circles, and efforts will undoubtedly be made to introduce it in the plant as a new and improved substitute for present time study programs. Its practical effect is virtually to abolish collective bargaining on production standards and piece rates."

Now, there you have it. Unions complain that "judgment leveling" is mere guesswork, and is what causes all the confusion. However, if we improve our techniques so that the guesswork is reduced, the union doesn't like such techniques because they tend to abolish

collective bargaining on production standards and piece rates.

Handling "Methods Change" Grievances

Labor Agreements generally say that the management shall not change an incentive standard, unless there is a change in the method of performing the task. This provision is the result of a desire to assure employees that standards will not be changed merely because earnings rise due to high effort. It is hoped, thereby, to make high effort more typical by freeing employees from the fear that the standard will be arbitrarily cut. Such a provision of the labor agreement should provide that when the methods are changed, the standard will then become inapplicable and a new standard shall be established for the new method.

The Prescribed Method Should Be Clearly Identified

By clearly attaching "standards" to "methods", arguments are reduced. Methods information should not be hidden away in the time study department. The employee performing the task and the foreman should be able to look in a box of cards and find the prescribed method for each standard. If such instruction is not available, the employee will say when a motion pattern method change is discovered, "This is the way I have always done this job. Nobody told me how to do it." You would then have a more difficult argument on your hands, if the standard is changed to reflect a difference in motion pattern, than if you can reply, "Why didn't you look in the box? The instructions on how each job is to be performed are always there." The methods descriptions in that box become management instructions, and are proper instructions under the general rights of management to "direct the working forces".

An Incentive Standard Should Become "Inapplicable" When There Is A Change In Method

Incentive standards should automatically become "inapplicable" if a methods change occurs. However, many labor agreements provide that incentive standards "can be changed" if there is a change in the method. There is a very subtle, but very important, difference in those two concepts.

If by the operation of the labor agreement, itself, the incentive standard becomes "inapplicable", a *new* standard must be constructed for the *new* task. If management merely has the right to "change" the incentive standard, the "old" incentive standard remains a proper one until the management changes it. An incentive standard for producing a part on an old hand screw machine, oddly enough, will be the proper standard for producing the same part on an automatic screw machine until it is changed under such a theory.

The basic difference between these two ways of expressing closely related ideas is that the standard is attached directly to the method, and *not to the part number* when the labor agreement provides that the standard automatically becomes inapplicable if there is a method change. Where management reserves the right to change a standard, if there is a methods change, the standard is attached to the part number. Since the starting point is wrong, confusion will result. Good incentive administration requires employee acceptance of the necessary changes in standards, and such acceptance is gained more easily if there is clarity of concept and expression. The subtle difference in concept between (1) "standards are attached to the method" and (2) "standards are attached to the part number" can grow into deep-seated misunderstandings - just like the little acorn grew into the knarled oak.

The Foremen Can Be "Sold" Their Obligation To Report Methods Changes

If an incentive standard becomes inapplicable automatically if there is a method change, it is easier to get the foremen to report methods changes. It is more serious to pay an employee under an inapplicable standard than to pay under one that is not "inapplicable", but could have been changed.

How to get prompt reports of methods changes from foremen is an ever present

problem. Engineers make their pleas for prompt reporting, but foremen say to themselves: "Well, if I do that - if I report little ones - the boys I work with won't like that. That industrial engineer doesn't have to live with those men." The foreman leaves the conference unconvinced, and so the "little ones" and many of the "big ones" don't get reported. If fear that the employees they supervise "won't like it" is the reason for the failure of foremen to report methods changes, that belief should be corrected.

Employees Like A Foreman Who Is A Good Incentive Policeman

The University of Michigan recently finished a very elaborate study of the attitudes employees in a very large and progressive manufacturing company. The management was interested enough to find out what employees thought about some of these problems. The Michigan study correlated together many employee answers, and a very interesting discovery was made. *The attitude of workers toward an incentive system is best when they work under a foreman who is a good incentive system policeman.*

The Payment Of "Average Earnings" As An Hourly Rate Can Never Be Justified

No discussion of incentive systems and labor agreements can be concluded without considering the wisdom of paying "average earnings" as an hourly rate under various situations. The answer to whether such payments can ever be justified is an unqualified *"NO"*.

The payment of "average earnings" as an hourly rate, even under the most limited circumstances, is a cancer that will continue to grow until, ultimately, the incentive system is destroyed. If such practices have started, they must be eradicated. If the eradication requires a strike, a strike on this issue may be a very wise investment. The long run health of the incentive system is at stake.

NUMERICAL CONTROLS - ECONOMICS AND USES

by MYRON S. CURTIS
Vice President, Engineering
THE WARNER & SWASEY COMPANY

Myron S. Curtis was born in Holbrook, Mass., graduating from Pawtucket High School and Brown University at Providence, R. I., where he received his degree in mechanical engineering in 1907. Thereafter, for a period of approximately thirty years, he was affiliated with the Potter & Johnston Company of Pawtucket, serving successively as chief engineer, works manager, vice president and director. In 1939 Mr. Curtis moved to Cleveland, Ohio, to lead a joint project of the National Machine Tool Builders' Association and the Ordnance Department and in 1940 he joined The Warner & Swasey Company as assistant director of engineering. In 1948 he was appointed director of engineering and a director of the company, and in 1953 engineering vice president. Although Mr. Curtis officially retired from this position in March of 1961, he remains active with the company in a consulting capacity.

Mr. Curtis is a member of the Cleveland Engineering Society and the American Society of Mechanical Engineers, and has in the past served in several official capacities with both of these organizations.

NUMERICAL CONTROLS - ECONOMICS AND USES

By MYRON S. CURTIS

Vice-President - Engineering, The Warner & Swasey Company

INTRODUCING THE SUBJECT

THERE have been a great many advantages attributed to numerical control of machine tools, but some of these, including reduction in human error and faster cycle time, could be accomplished by other means such as special or automatic machinery. However, there are other hidden benefits that tie into the economics of numerical control which are just as real and must be recognized.

WARNER & SWASEY'S EXPERIENCE WITH THE ECONOMICS OF NUMERICAL CONTROLS

At Warner & Swasey, our investment in numerical control equipment has given us the expected benefits of fast response to manufacturing orders, greater flexibility in design and manufacturing, improved production skill, and better quality. As an added benefit, numerical control has caused us to be more critical of our present technology by consistently revealing and highlighting operational and organizational deficiencies.

As a working concept, numerical control becomes in effect a management tool, for more efficient planning and production. A wider use of it in our plant cannot help but improve our entire business operation.

NEW APPLICATIONS OF NUMERICAL CONTROL

The trade magazines have been full of publicity about various pieces of equipment which are numerically controlled by one system or another. There is no need to review all of these again here. However, there are a few new applications which have not been as widely publicized. These will be discussed partly as a matter of adding to our fund of knowledge, but also as a means of stimulating our imagination to anticipate what the future may bring in the application of this new control concept to manufacturing operations. Slides will be used to describe the following:

1. The Warner & Swasey Servofeed Turret Lathe with its unique memory system.
2. A numerically controlled flame cutting machine.
3. Non-machining applications including (a) a tape controlled electrical panel checking machine; (b) a tape controlled layout machine.

Some of the above applications of numerical control, particularly as applied to inspection-type equipment, are in the early stages of development, and economies and benefits are yet to be proven. That they will prove beneficial to the manufacturing operation, there is little doubt. It is a matter of time and the reduction of the cost of the control systems themselves, and when these costs come down within reason, as they inevitably must, a host of new applications will come along.

SUMMARY

To summarize our discussion briefly, we have said that some of the economies of numerical control could be accomplished by other methods, but there are many hidden benefits which can be realized with proper coordination and teamwork of all aspects of the production operation, from design through planning and actual manufacturing. Although it is not and will not be a panacea for all manufacturing problems, numerical control is with us to stay and new applications are coming rapidly. However, like any other development, it must stand on its own feet economically.

PERT - AUTOMATED R AND D MANAGEMENT INFORMATION SYSTEM

by D. G. MALCOLM
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PERT--AN AUTOMATED R & D MANAGEMENT INFORMATION SYSTEM

By D. G. MALCOLM

Vice President - Western Division, Operations Research Incorporated

THE PERT information system, designed to provide progress information to the management team of the Navy Polaris program is a significant example of what modern industrial engineering, working in conjunction with operations research and computer specialists, can achieve. PERT, which stands for Program Evaluation and Review Technique, was created by a "system design" approach quite similar in its scope and orderly development to the approach taken in the development of hardware items. It is the purpose of this discussion to describe the basic PERT system, its current extensions into the Cost and Reliability areas, and to touch briefly on some industrial applications being made.

PERT was designed to deal with the measurement and control of *TIME*, i.e., compliance to plans, scheduling, planning and prediction of progress. Other management research in this area, by the Navy, the Air Force and industry, is extending the PERT concept into measurement and prediction of *Cost* and *Performance*--where performance refers to the performance of the item under development.

Admiral Raborn, Director of Special Projects Office which has managed the Polaris program, often tells his people that "If you can think out a plan, you can also write it down". This message supports the planners to encourage their technical staffs to reduce to writing the ideas they have in their minds. This is a necessary first step in "creating on schedule". Lt. General Schriever, Commander of the Air Force Research and Development Command which develops the many weapons systems of the Air Force, has stated that one of their most serious problems in space and missile development lies in the development of management methods themselves. These two men, encharged with a large portion of our creative R&D, have thus laid down a challenge to all of us who are working in the management systems area, to develop management systems which can keep up with the technology that we are rapidly acquiring in the development of missiles and space vehicles themselves. Both men endorse PERT, the subject at hand, as a tool necessary in the reduction of both time and cost in our defense effort.

It has been the concept of "concurrency", i.e., concurrent design and development in order to reduce development time, that has created the need for a new technique, predictive in nature and able to cope with concurrent, interrelated activities thus created. The increased coordinated and attendant information required are shown in Figure 1, which illustrates the added number of interactions required to operate in a concurrent fashion.

Admiral Raborn, in setting up PERT, has recognized the need for a significant effort to develop the management tools that go along with the creative technical work that is involved. Recognition of this problem and putting research time and effort against it is a rather unique contribution in and of itself, for it generally is quite difficult to establish research projects in the operational management area.

Since initial application in Polaris, the concept has spread through several Air Force, Navy and Army programs and is being used in private industry for the management of the new product activity, where savings on the order of 20% have been claimed.

The Navy's program in PERT was part of a time-phased program much the same as we see in the development of a missile itself. We speak of generations of missiles, each one

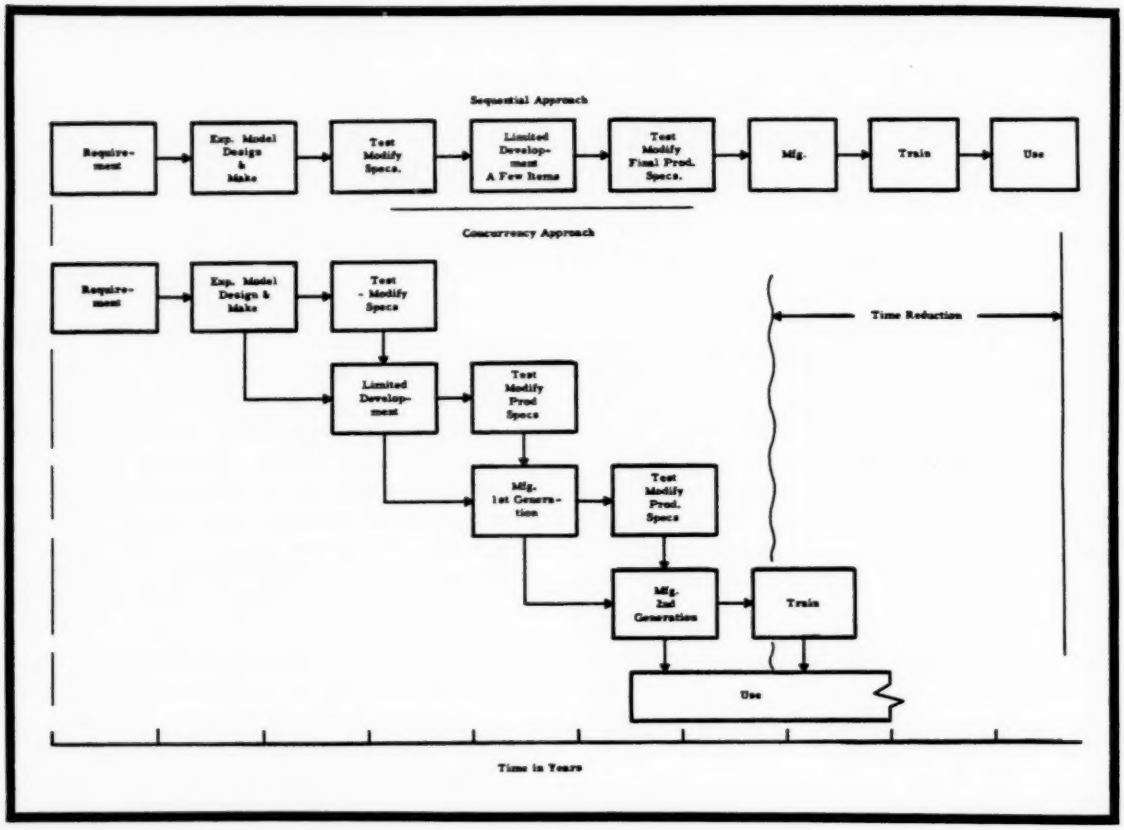


Fig. 1. Shortening The Time For W. S. Development

having greater range and other operational capabilities than the preceding generation. Likewise, in establishing management systems, the concept of going at it in a series of generations was conceived, and PERT represents the first such generation of a management information system. It tackles primarily the problem of *Time* compliance in a development program. Second and third generations of this management system are currently under development in the Navy: one in terms of *Cost*, dedicated to integrating cost or resource information with the time information; and another which is tackling the Performance, or reliability, measurement and control. In the latter area, it is hoped to provide a foreward look at what the reliability problems are early enough to make the most useful tradeoffs and reallocation of resources.

A DESCRIPTION OF THE PERT APPROACH

In the PERT approach, the development program is first portrayed graphically as a network of interrelated activities necessary to achieve prescribed milestones, or events. Figure 2 shows a typical network or flow plan for a small portion of the Polaris program. *Events* are shown as squares in the diagram and *activities* as the connecting arrows. The "critical path" is the longest path through the given program. It is this part of the program that management is most vitally interested in determining, shortening and monitoring. The computer has been programmed to sort out from the many concurrent paths, which is the longest and next longest, etc. Figure 3 sums up some of the major definitions used in PERT.

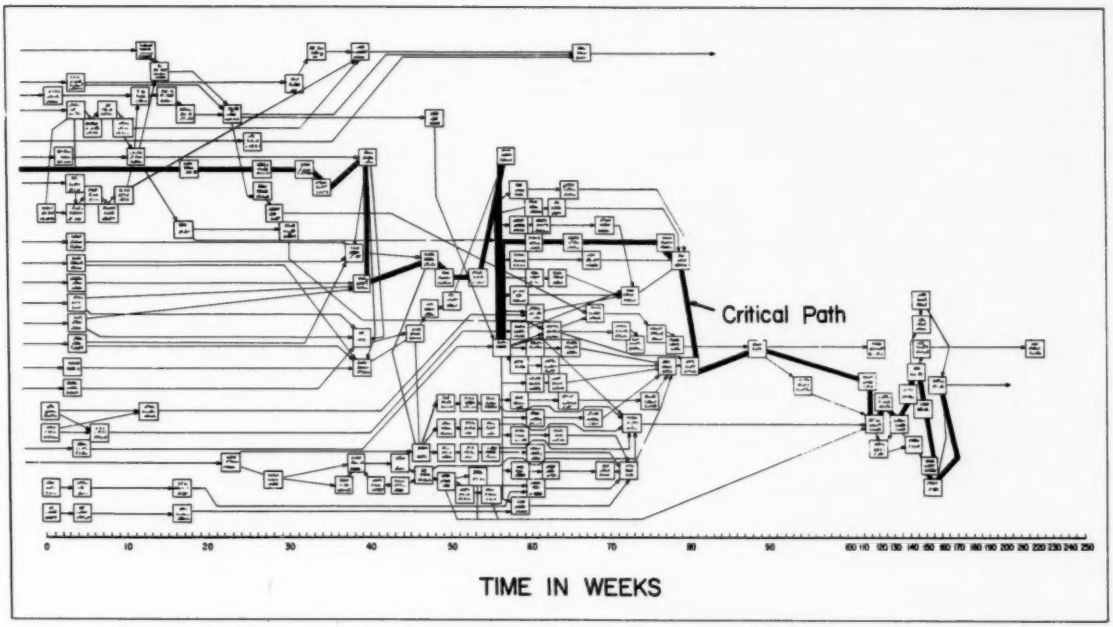


Fig. 2. PERT System Flow Plan or "Network"

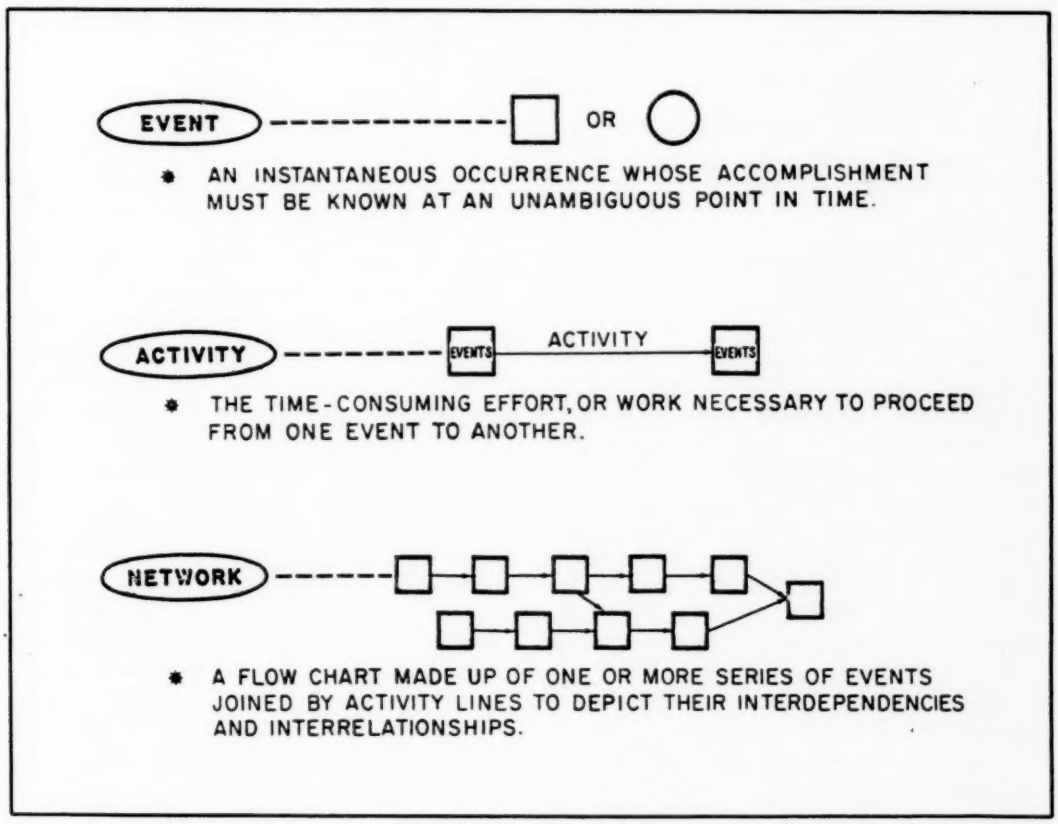

EVENT
OR
AN INSTANTANEOUS OCCURRENCE WHOSE ACCOMPLISHMENT MUST BE KNOWN AT AN UNAMBIGUOUS POINT IN TIME.
ACTIVITY
EVENTS
ACTIVITY
EVENTS
THE TIME-CONSUMING EFFORT, OR WORK NECESSARY TO PROCEED FROM ONE EVENT TO ANOTHER.
NETWORK
A FLOW CHART MADE UP OF ONE OR MORE SERIES OF EVENTS JOINED BY ACTIVITY LINES TO DEPICT THEIR INTERDEPENDENCIES AND INTERRELATIONSHIPS.

Fig. 3

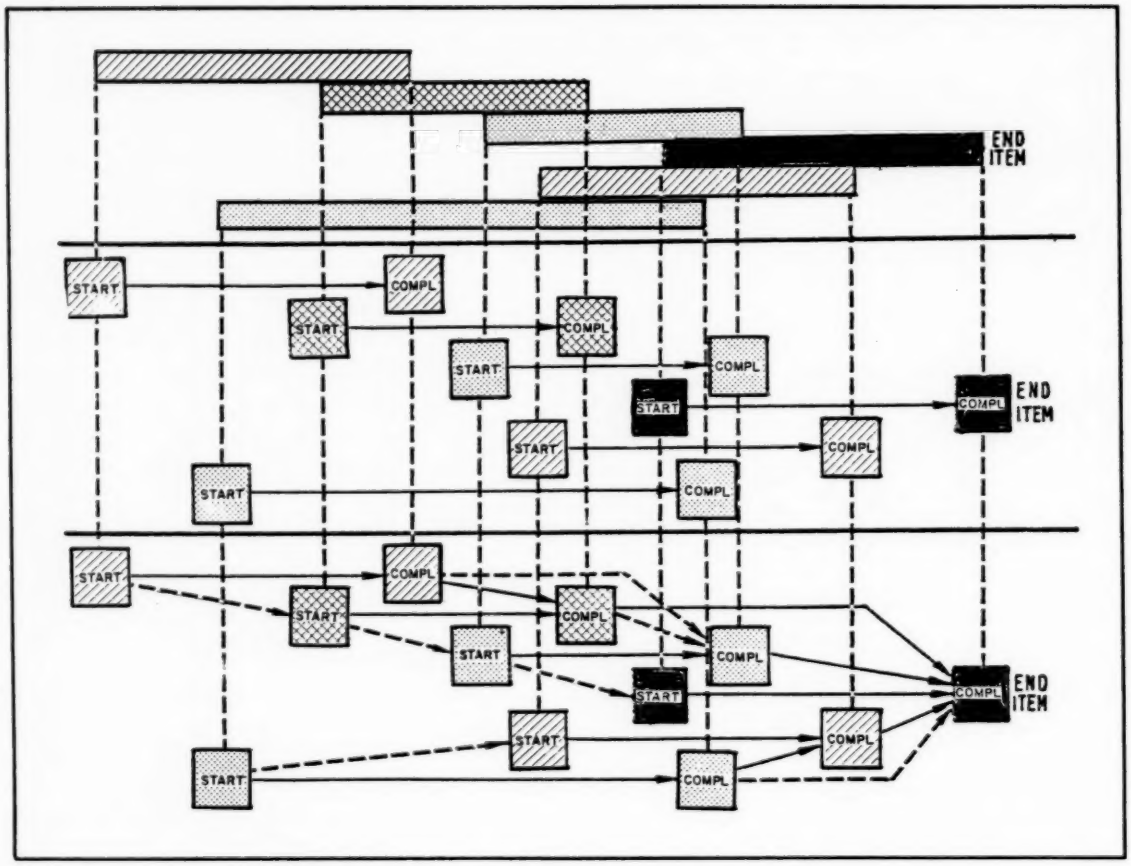


Fig. 4

The relationship of the network approach developed and used in PERT and traditional Gantt charting is worth commenting on. Figure 4 illustrates this difference. In Gantt charting there is no dependency, or interconnection, between activities shown. Coordination functions and precedent relationships are not shown in Gantt charting; these are of major significance in large R&D programs where many activities must be performed concurrently and be properly coordinated. Planning for these points and utilizing this plan in monitoring makes it more nearly possible to "create on schedule"--a requirement in our current weapons system program. The use of the "network" is thus a significant innovation to the body of Industrial Engineering techniques.

The next step in the PERT process is to obtain elapsed time estimates for each activity in the network from engineers responsible for their completion. Three estimates are obtained for each activity, representing the range of time which can be expected. These estimates--optimistic, most likely and pessimistic--are transformed into a probability statement indicating the chances of the activity taking different lengths of time to be achieved. The flow plan and time estimates are then fed into a computer which computes and sorts out the longest path from all the possible paths to any event. All other paths to an event thus have "slack" in them and represent areas where resources may be reallocated. The path having zero slack allocated with it has been termed the "critical path" (see Figure 2). Thus PERT is a "Management-by-Exception" tool providing the manager with information where slips are likely to occur and what their magnitude may be. It also indicates where slack exists in the program and is guide for reallocating some of the resources to reduce total program time. This identification of

slack areas also forewarns the manager of where *not* to buy attractive time reduction opportunities that may be proferred.

EVENT NUMBER	EXPECTED TIMES		LATEST TIMES (T_{OL}* T_{OE})		SLACK $T^*_L - T_E$	ORIGINAL SCHEDULE T^*_s	PROB. OF MEET'G SCHEDULE
	T_E* EXPECTED	VARIANCE	T^*_L EXPECTED	VARIANCE			
50	92	38	92	0	0	82	.05
51	85	35	85	3	0	77	.09
54	74	29	82	4	8	73	.42
52	47	25	74	7	27	70	1.00-
53	70	31	70	7	0	60	.04
55	35	18	62	14	27	55	1.00-
56	60	26	60	12	0	50	.02
57	56	23	64	10	8	55	.42
•	•	•	•	•	•	•	•
•	•	•	•	•	•	•	•
•	•	•	•	•	•	•	•
X-NOW	0	0	•	•	•	•	•

*(TIME IS SHOWN IN WEEKS FROM X OR TIME "NOW")

Fig. 5. Outputs From Analysis

In Figure 5 typical data available to a manager are shown. Use of the three estimates makes it possible to develop a probability index for meeting or beating the schedule. The magnitude of this number may be used as a guide for determining the relative seriousness of the potential schedule slip or for rescheduling. In operation, PERT is maintained and updated according to a regular plan. Figure 6 is such an operating description of PERT. An-

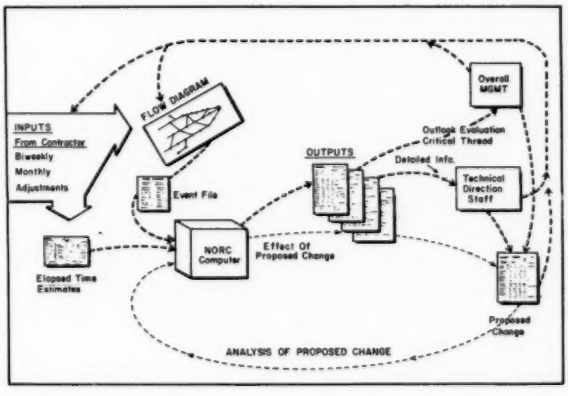


Fig. 6. PERT System in Operation

other feature of PERT is the possibility for "stimulating" a change. The manager may introduce a synthetic time reduction and find out what would happen to the total program as a result. Often time-reducing changes do not buy equivalent time reduction in the program and may better be rejected. Many displays are possible from the data available in the PERT computer files. Figure 7 is illustrative of

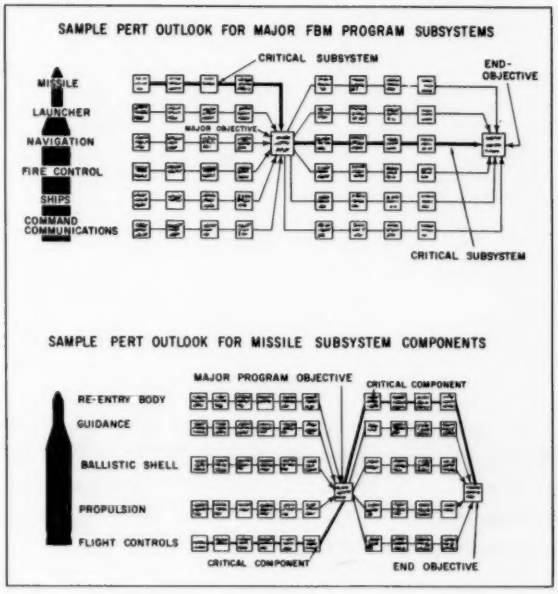


Fig. 7. Integrated Outlook

how critical paths at higher management levels in the program can be developed by aggregating the data. A variety of such reports are available.

Figure 8 assesses the role of the Computer in PERT. It is highly important for management to specify what it wants out of the computer, and not have the computer lab tell management what it wants. It has happened often in the use of the PERT technique that the computer lab can see many possibilities of analyses and outputs of interest to them, which end up complicating the situation and making it difficult for management to see the real simplicity of the technique. The "management system design function" is one the industrial engineer fills--a sort of buffer between

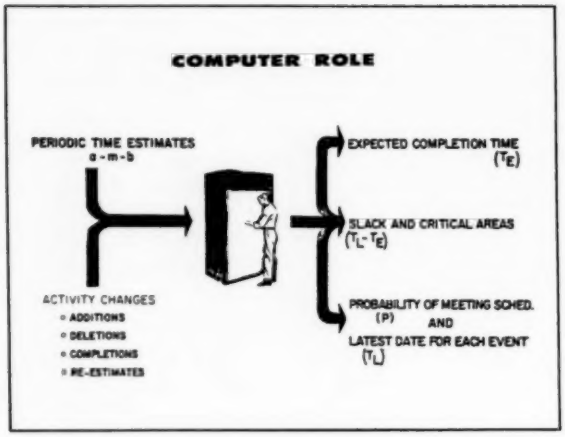


Fig. 8

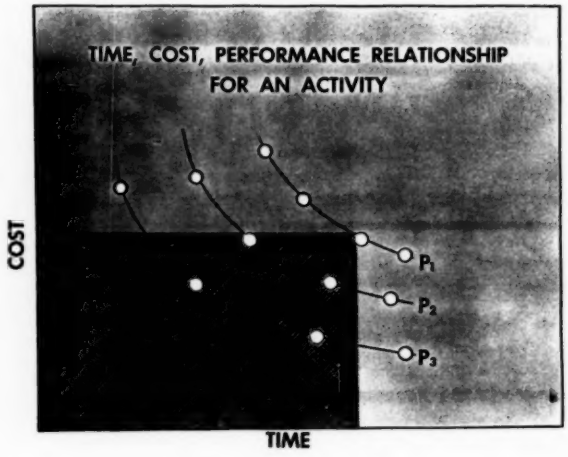


Fig. 9

management and the computer lab. He knows the needs of management and is able also to communicate effectively with the computer specialists. The role of the system designer is becoming better recognized as the requirement for improved management controls is made.

EXTENSIONS OF PERT

Up to this point, we have discussed PERT. Let us now discuss some of the problems involved in extending management systems into second and third generations. In the PERT approach, only time estimates are obtained. It is possible for each one of the time estimates to obtain a cost estimate. Generally speaking, it is recognized that at any given level of performance, if a reduction in the time of an activity is desired, it will take a disproportionate amount of resources applied to the task to get it done quicker. Further, if greater performance is desired at a given cost, it will take longer to achieve. Put in another way, for any given level of time, if greater performance is desired--i.e., a better missile--it will cost more and/or require more time. Figure 9 illustrates this relationship.

Early in the original PERT research, it was deemed impractical on two counts to cope with all three variables (Time, Cost and Performance) simultaneously in a computer model. First, related cost and time data on activities not experienced before are almost impossible to obtain with any degree of accuracy. It was almost impossible to get anyone to think significantly about such data. Further data on different degrees of the item's performance are even more difficult to obtain. Secondly, even if the data were obtainable, it would require a data processing load of about 20 times the data the basic PERT system requires. Therefore, it was reasoned that if the total integrated Time, Cost and Performance approach was taken at the outset, the cost and data problem would defeat acceptance by the potential user of the system. It was decided to tackle the time variable first and then go after the cost variable after the information channels had been established.

A PRINCIPLE IN MANAGEMENT SYSTEM DESIGN

One major principle in management system design that was followed in PERT and its extensions bears stating. This is the principle of taking a vertical slice of the program for the study effort and pilot installation. Figure 10 represents a technical or hardware

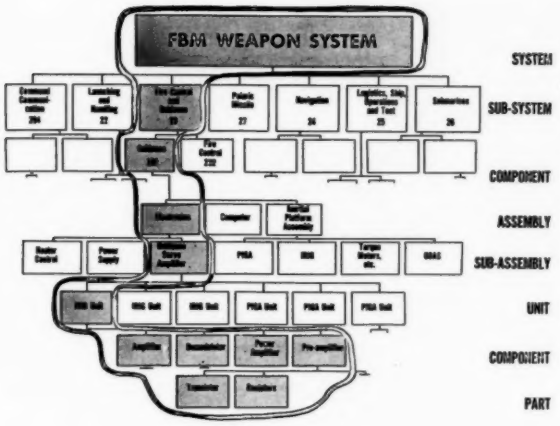


Fig. 10

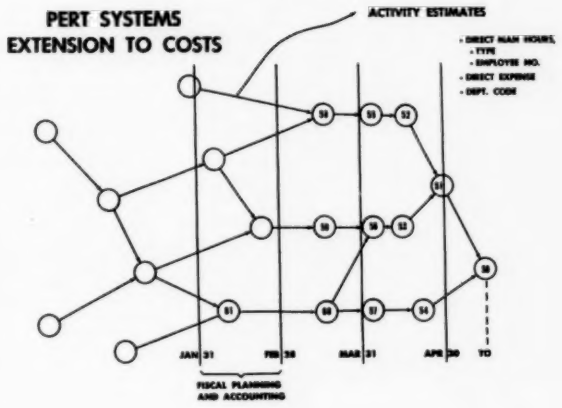


Fig. 11

breakdown of the Polaris System. The various subsystems are shown across the top and are divided into components, etc. It was decided in PERT that one had to go right down to where the work was done, i.e., take a vertical cut, rather than taking the traditional horizontal cut in order to get immediate total program results. In this way the ultimate system is completely consistent from top to bottom and one can have the confidence that data will be properly obtained and transmitted. After debugging this vertical slice, or pilot area, the system can be spread horizontally to other subsystems in a routine way.

COST EXTENSION

There are a number of ways costs can be assigned to activities. One, a range of possible costs could be applied to each activity; or, a single cost for each one of the time estimates in PERT could be made. Further, there is a choice concerning whether to use a single cost, direct costs, or total cost. As shown in Figure 11, PERT applications to date generally have applied direct man-hour costs, either in man-hours or dollars, to the activity, showing the department, code for the man, and in many cases identifying the individual man, where highly skilled individuals are a scarce commodity in great demand. Quite often in R&D, one particular designer is the only person who can do a certain kind of design job. It is desirable that he not be given too many tasks to perform concurrently.

The vertical lines in Figure 11 illustrate the problem of making PERT cost data compatible with regular fiscal practices already in effect. It is seen that planned activities cut across the orderly monthly accounting periods shown. It is possible to convert from PERT activities to financial planning and accounting by knowing the rate of expenditure, but it is *not* possible to work in the other direction in the absence of a PERT diagram. This then is suggestive of the proper order of application. In short, PERT costs should be considered an input to current accounting systems.

With data obtained as indicated, the following output reports are then possible in a company using the basic PERT cost approach:

- Expected Manpower Requirements
  - by skill, month and dept.
- Individual Man Loading
  - by month
- Expected Project Direct Costs
  - by skill, month and dept.
- Regular PERT Time Outputs
  - slack areas
  - critical paths
  - expected calendar time, impact prediction

Figures 12 and 13 show some of the types of data available from the cost system. It is noted that PERT Costs and Budgeted Costs

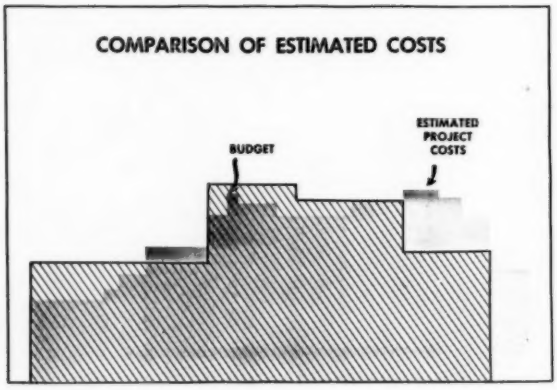


Fig. 12

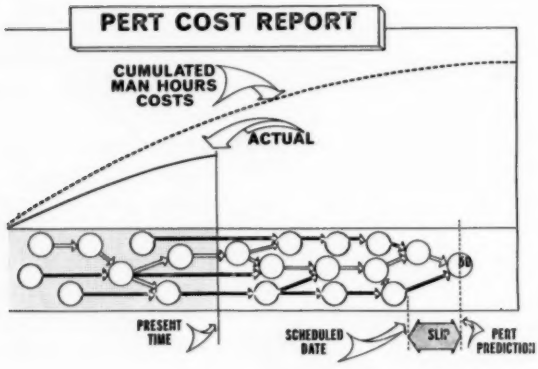


Fig. 13

may not always agree. Generally, PERT Costs will be lower and displaced in time due to the fact that all direct work may not be easily identified with networked activities.

In summary, PERT costs are being used to determine manpower requirements by both skill, time period or month, and the department. In several applications, technical directors have found they have overlooked certain technical skills and this has set up the need for looking for additional people in that skill category. Individual man-loading by month, expected project direct costs by skill, month and department are available outputs.

Cost outputs are being used in company planning for the following purposes:

1. Determining and improving utilization.
2. Balancing the work load.
3. Evaluating Cost-Time tradeoffs.
   When the first PERT cost outputs are available and management has used them in improving utilization and balancing the work load, there will be other opportunities to reallocate resources to activities or to apply new resources. The effect of these in regard to the over-all schedule, or time objective, may be easily evaluated by a simulated change, with the increment costs known. The effectiveness can be measured in terms of the time reduction to be achieved.
4. Determination of per cent of directed work.
   In the course of planning any project there will be peaks and valleys in the requirements for the services of individual skills and individuals in particular. Where knowledge of this can be ascertained in advance, the time may be scheduled for other productive work that the company has available or desires to do -- such as a directed research effort. Further, this per cent is a good project control device for management.
5. Scheduling of manpower build-up.
6. Identification and assignment of technical work.

From the above it can be seen that the PERT network is capable of supplying basic information useful in planning, that this information is consistent with the definition of the planned and scheduled activities, and that it is possible to utilize this information in normal fiscal channels. It appears that this approach, which may be called "operational accounting", in the R&D field, provides the necessary bridge or "common language" between planning and scheduling activities and fiscal accounting requirements.

PERFORMANCE

Turning to the third component of the management problem, the "third generation", if you please, of the Polaris management system research activities--this has been titled Project PRISM, which stands for the Program Reliability Information System for Management.

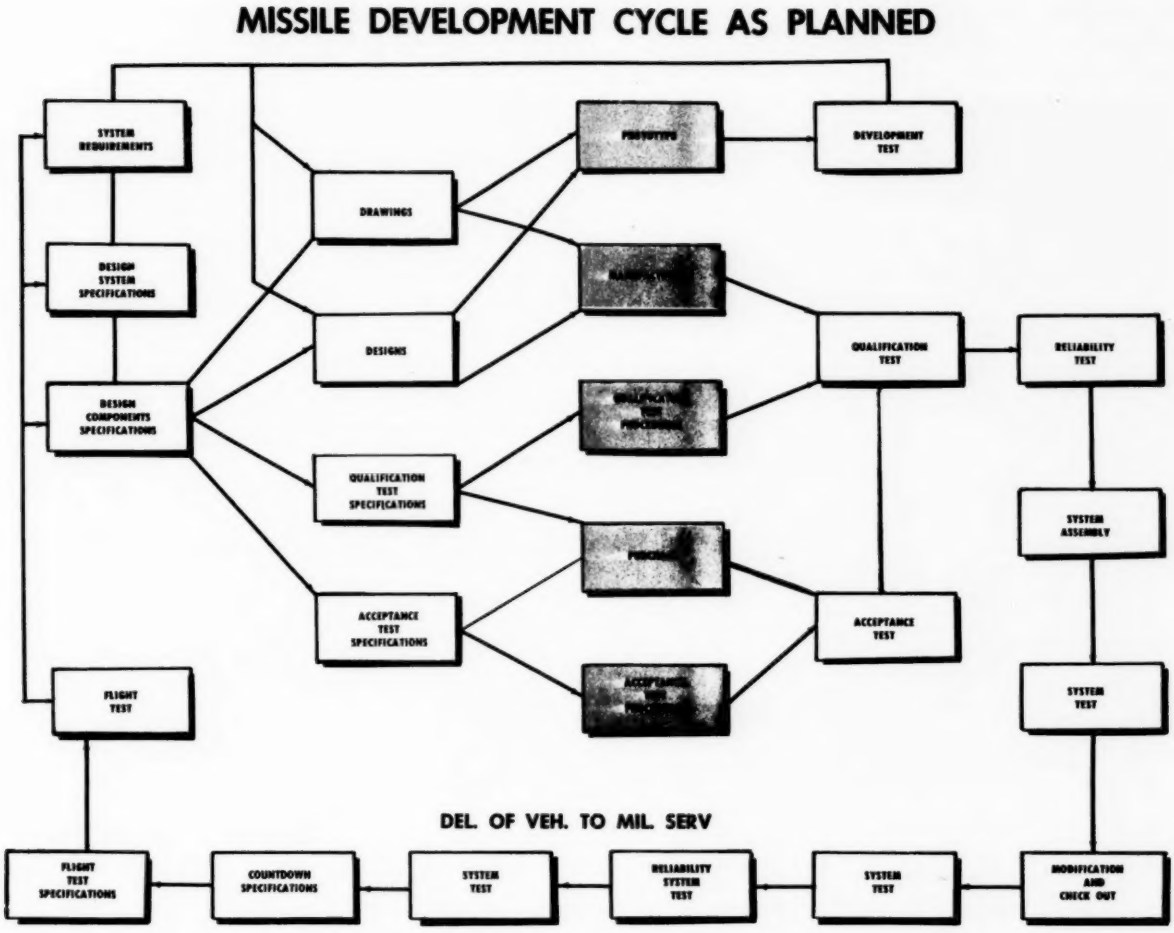


Fig. 14

The objectives of the project are twofold:

1. To develop a capability to provide performance tradeoff information concerning the program approximately two years in the future, and
2. To develop a capability to quantitatively depict the expected reliability at the subsystem level.

Two basic approaches in developing program information are under consideration at this time by the project:

1. *Monitoring development plan compliance, or the RMI method* (Reliability Maturity Index). Under this method the development cycle as shown in Figure 14 is monitored to see that test specs, test procedures, acceptance procedures, etc., are written in accordance with the schedule set up. Each item of an assembly is rated in accordance with the factors shown in Figure 15. Check lists are built up for each of the rating factors shown, permitting a rating from zero to 1 to be assigned. The composite rating for each item represents an index of the reliability maturity. Management use of this information is directed toward low indices and zero compliance areas by appropriate sorting routines and report displays.
2. *System reliability prediction.*

RELIABILITY MATURITY INDEX (RMI)

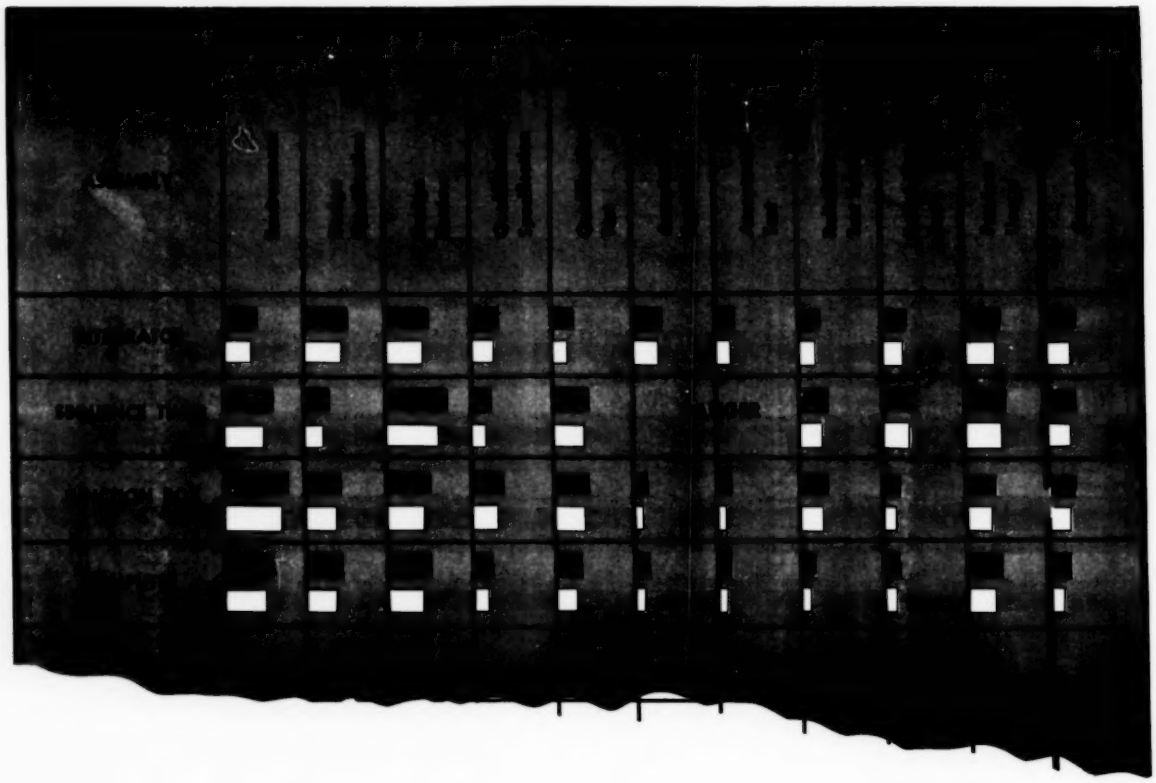


Fig. 15

The RMI method provides a measure of compliance and does *not* develop a numercial forecast of the eventual operational reliability of the end item. Since one of our most needed capabilities is the prediction of the eventual logistic requirement and operational up-time to be realized in practice, it is desirable to obtain a forecast number that can be used as a planning factor. The SP research program is developing a method known as RPM (Reliability Performance Measure) involving the following steps:

a. *Development of an operational model of the FBM System.*
   This model is used to estimate the per cent of successful launchings and utilizes data available from analyses of performance at each phase of the development cycle.

b. *Development of methods of analysis.*
   Analysis methods are being developed which will predict reject rate and fleet failure rate. Different methods are required for preliminary design, design development, manufacturing logistics and operational phases of the development program.

c. *Development of a method for synthesizing component and subsystem estimates into a total system estimate.*
   The reliability estimates are made for various components, and subsystems are combined to make a total system reliability estimate (% of successful launchings).

d. *Development of an information system.*
   A rapid means of collecting, analyzing and reporting information to technical

managers is being developed.

e. *Comparison with reliability requirements.*
Using the predictions of Item (d), it will be possible to compare the predicted reliability with the reliability requirements, or goals, set up in the original technical plan. Further, use of the computer model will permit the effect of changes in the failure rates of components and subsystems upon the total system reliability to be appraised.

As these concepts are developed, it will be possible to provide management with a set of tools that will aid in enforcing the development plan, also a quantitative number predicting the reliability of the item under design will be available at all stages in the development project. From this number it will be possible to detect weak spots in the program and to initiate specific remedies. Figure 16 illustrates the objective of the reliability information system to focus on the ultimate use at all times during development.

Here again it should be noted that the management information system purports only to develop information and does not make decisions. In short, the concept is conceived to aid the decision maker and not to replace him. It should be further noted here that there are many pitfalls and problems in devising an appropriate reliability system.

INDUSTRIAL APPLICATIONS OF PERT APPROACH

The PERT approach is being experimented with in a number of industrial areas. One that

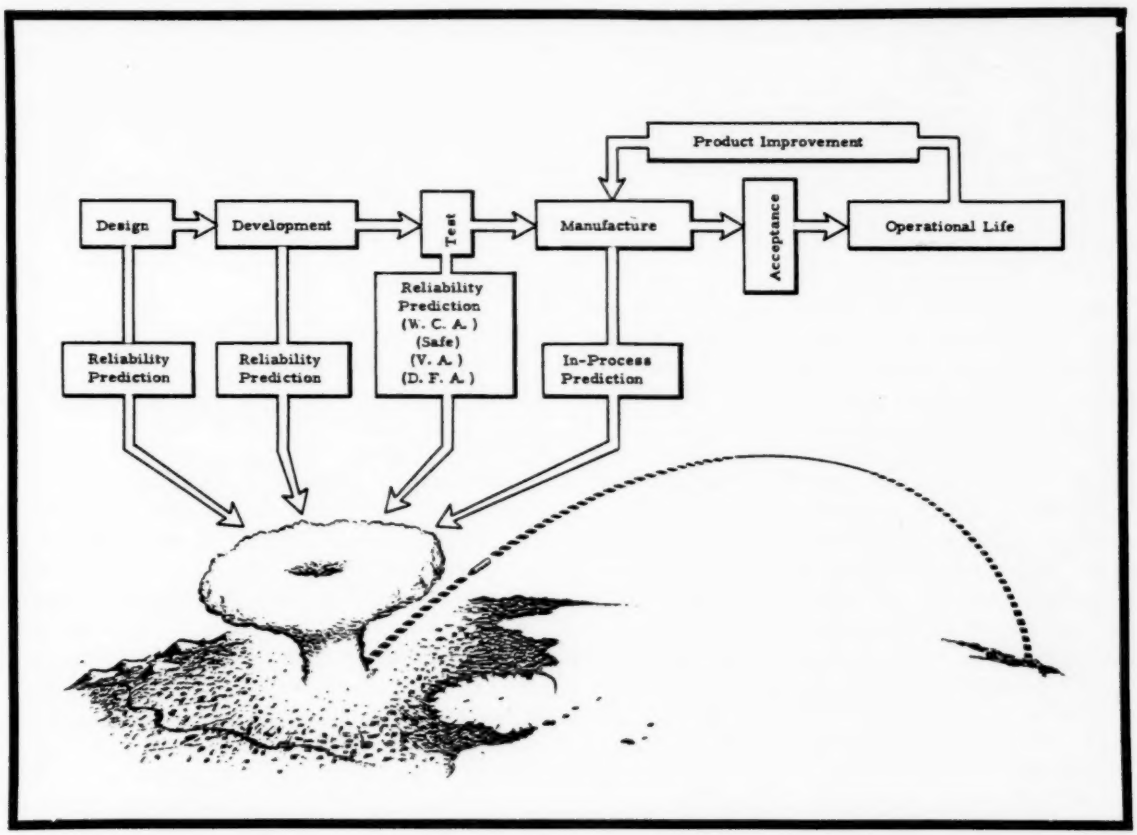


Fig. 16. The RPM Function

is under way in one of our large companies is attempting to utilize the PERT approach in the new product process. American industry is putting more and more money in research and has a major problem in determining whether it is getting a payoff on this investment. Further techniques for planning and controlling R&D functions are still embryonic in nature. A way to predict and plan for the timely and efficient exploitation of company research results is most needed. Figure 17 depicts the steps in developing a new product--a process that takes about 6 to 7 years for the average new product.

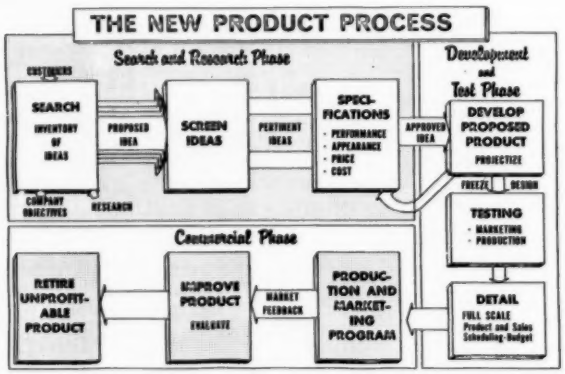


Fig. 17

First, there is the task of searching out ideas and doing fundamental research. There are three areas shown in the Search and Research phase. The next phase is the broad area of development and test, or the development test phase, where selected ideas are brought up through reality of a pilot product. Coordination with the various other functional areas in the company is most important at this stage. The marketing, engineering and manufacturing areas all get involved because each has an eventual responsibility. Finally, if the test product is deemed feasible, it is moved into the commercial phase where it becomes a part of the product line. Out of 400 or 500 ideas, only one or two ever reach the commercial phase.

The objective, therefore, in research and development is to attempt to get the new product process performed efficiently and in a minimum time. Yet, in many companies the mode of organization works against getting new products out in a reasonable time.

Figure 18 represents such a typical industrial concern which is functionally organized--top management with sales, research engineering, distribution and production shown, each having a say about everything that goes on in current operations; research generally responsible for coming up with the new ideas and hopefully having them well enough brought out so they will move on into production and sales quickly.

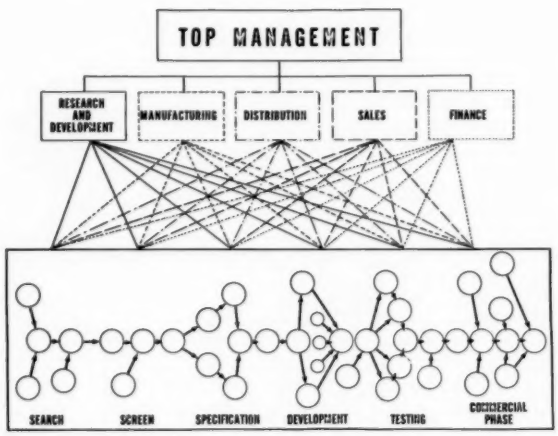


Fig. 18

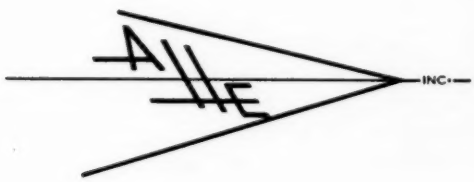
Across the bottom of Figure 18 this new new product process is shown--the search, screen, specification development, testing and commercial phases. Superimposed over these phases is a PERT diagram in the aggregate that shows the searching for ideas, selecting of promising ones for further refining, specifying what is to go into development, performing development tests. Moving across to the right represents the passage of time, with the lines coming down from the top in spider-web fashion indicating that almost all of the functional areas get involved in each of the various phases. Generally the various functions are not involved in a coordinated way. The idea of creating a project management concept for the product early in the game and using PERT as the management tool to cut across the functional lines appears promising and follows logically after a project network is set up. This use

of PERT will have an effect on the traditional functional organization. Some refer to this as turning the organization 90 degrees and focusing on the project objectives. A project manager is required who can reach out for the necessary staff and systems analysis he needs all throughout the program. In this way the whole organization can be coordinated and brought to bear on a new product objectives.

The companies that are involved in this confidently expressed the fact that they believe they can cut the cost of the development of new products by at least 20%, both in time and cost, due to better coordination between the functional areas of the company early in the game, on a planned basis, where everybody knows what their function is to be.

Several other applications of the networking concept have been suggested--long range planning, maintenance and construction activities, to name a few.

In conclusion, the PERT approach offers opportunity for industrial engineers to develop better planning and control tools to aid in the management of the R&D process. Such predictive controls are vitally needed to unharness and realize the benefits of American R&D more efficiently as well as quickly.



STORM SIGNALS OF THE SIXTIES

by **RAY R. EPPERT**
President
BURROUGHS CORPORATION

Ray R. Eppert was born in Carbon, Indiana, in 1902. After completing his education, he worked for a time for the Denver Post in Denver, Colorado, and later became associated with the Park Hotel in Rock Springs, Wyoming.

In 1921 he joined the Burroughs organization as a shipping clerk at the Ogden, Utah, branch. Two months later Mr. Eppert became a sales trainee, and within another two months, was named a senior sales representative.

In 1926 he was promoted to the Bank Division of the Burroughs Home Office Sales Promotion Department in Detroit. Two years later, he became Assistant Branch Manager in New York City and, subsequently, Special Representative of the Eastern Division.

He returned to Detroit in 1933 and within six years was made Assistant General Sales Manager. He became General Sales Manager in 1941. Five years later he was appointed Vice President in charge of Marketing.

Elected a member of the Board of Directors in 1948, Mr. Eppert, in 1951, became Executive Vice President. In April 1958 he was elected President of the Corporation.

Mr. Eppert is a trustee of Hillsdale College, which awarded him an honorary doctorate of humanities in 1956. He is also a member of the Lay Board of Trustees of the University of Detroit.

STORM SIGNALS OF THE SIXTIES

By RAY R. EPPERT

President, Burroughs Corporation

IT WAS the naturalist, John Burroughs . . . no relation to our company, by the way . . . who admitted that he was born with a chronic anxiety about the weather.

In similar vein, we businessmen have a chronic anxiety about the business weather -- the economic climate in which American industry must operate. Except for a few short squalls, we have been basking in an exceptionally favorable climate during the postwar years. Yet the "Soaring Sixties" which we welcomed so confidently about a year ago haven't been able to gain altitude . . . indeed, some of little faith already are referring to the "Souring Sixties".

For myself, I share the more widespread conviction that we are presently experiencing another squall which will lift in the coming months. However, I also have the conviction that there are at this moment several economic storms brewing which could be the signal for a drastic and unhappy change in the business weather cycle.

Fortunately, business isn't entirely like the weather. We can do something about it as well as talk about it. Today, I want to *talk* about this business weather . . . and what we can *do* about it.

We have proved conclusively since World War II that we can produce at any necessary or desired level. The question now has become: at what level can we distribute and sell? A production schedule which ties up needed working capital in excess finished goods inventory is doomed for a very short life. Productive capacity without a market is like money to a starving man at sea.

With a very few exceptions, the emphasis in the United States has shifted from production to distribution. Marketing executives are in the spotlight and on the spot.

It is with no thought of being a crepe hanger or a calamity howler that I point to these storm signals on the marketing front. Even in its present doldrums, our economy is at a generally high level, and I don't want to sound like the farmer who harvested a bumper crop after successively predicting his own ruin as a result of freeze, flood, drouth and disease.

"It turned out pretty good," he confessed, "but don't you know, a crop like that sure takes a lot out of the ground."

I only want to make the distinction that we have the opportunity, but not the assurance, of fair and warmer days ahead. Because we have good seed in the ground, we can't sit back and wait for the harvest. We have work to do.

And now for a look at the weather map.

First, there is a very, very cold front generating from eastern Europe in the area of Moscow. Behind it is a violent storm already covering a third of the earth's surface. This one is a snow job of the first order and, unless dissipated, could bring a deep freeze to the whole democratic world.

Wherever this front meets with our own trade winds, there is considerable turbulence at all elevations.

Next, concentrated over the European Common Market, the European Free Trade Area, and other strongholds of vigorous individual enterprise are a series of growing counter-fronts. These are "friendly" weather breeders to the extent that they help resist the Moscow storm system, but at the same time they are threatening our American markets with extensive precipitation.

Finally, here at home we have developed a long-standing high pressure area with strong political winds. While this system promises showers of prosperity, all too frequently in the past similar movements have turned out to be nothing but hot air masses which parch profits and dry up the seed.

Now . . . what can we do about this weather?

We can and must create our own favorable climate with aggressive marketing programs, at home and abroad.

Through the centuries, many nations have taken their turns in dominating world commerce . . . each succumbing at last to a stronger competitor. As the leader for the last thirty years, we have this much in common with our predecessors: *We continue to grow, or we die. We keep running, or we get run over.*

We have one tremendous advantage over the power nations of the past. They were essentially *trading* nations whose economic growth was limited by the amount of goods they could produce or obtain. The United States alone has come into power as a *producing* nation.

We can, in short, produce all we can sell. Our problem is to sell all we can produce. To maintain our world leadership, we must become the first great producing *and* marketing nation. If we don't, there are others who will.

Looming most ominously is the Soviet Union. Nikita Khrushchev made that plain enough when, during a comparative lull in the cold war, he bluntly stated:

"We declare war. We will win over the United States. The threat to the U.S. is not the ICBM but in the field of peaceful production. We are relentless in this and will prove the superiority of our system."

That, gentlemen, is not a statement to be taken lightly. While we may be poles apart in ideologies and economic systems, Russia has this in common with us: she controls most of the physical resources required for her economy. That is essentially what made us a producing nation, and it would be foolhardy to question but that Russia can do the same . . . in time, and if her system holds together. We can't afford to gamble on her failure. We must stay well out in front.

Hand in hand with the Soviet production drive is a marketing drive. Again, our authority is the terrible-tempered Mr. Khrushchev himself, who has stated: "We value trade least for economic reasons and most for political purposes."

That aim has been clearly demonstrated in recent months in Africa, in Asia, in Cuba . . . wherever political unrest has offered an opening wedge for the Communist trade offensive. Nor are the Soviet efforts confined to the economically underdeveloped areas. Only the other day I read a newspaper story concerning Soviet-refined gasoline which is being offered on the European market at cut-rate prices. Owing to poor refinery equipment, the exhaust fumes from their gasoline smell like rotten eggs -- a pretty obvious marketing disadvantage -- but it is reported that the Soviets are modernizing their equipment and expect to overcome this difficulty in the near future, whereupon they may become serious competitors in the European petroleum market.

With the Soviets, we are not facing independent businesses like ourselves or those of our allies. With the Soviets, trade does not follow the flag; the flag follows trade. With the Soviets, we are coming to grips with the whole power of their government which, since all profits belong to the state, can price their exports on any basis their political ends require. Then, if they desire, they can offset these actions merely by increasing prices at home.

This is an advantage we do not have . . . nor, at the cost, would we want.

In the end, this struggle will be decided in favor of the economic system which demonstrates that it can do the most to improve the living scale of the most people. We confidently believe that we have that system, but we must prove it to the rest of the world. Our only sensible strategy is to improve the economic strength of the non-Soviet world, to bind together the nations of the free world with strong trade links, and to pursue a vigorous policy of maximum international commerce. Marketing must play a leading role in these objectives.

On this score, let me cite just three figures. In 1959, our export sales to West Germany amounted to $14.75 for every West German man, woman and child. The Japanese per capita purchase of our goods was a little over $10. Pakistan could buy only $1.15 per capita from us.

These figures suggest two conclusions which have a hen and egg relationship: First, it is to our advantage to build up the purchasing power of underdeveloped nations; second, our strongest Free World competitors are our best customers.

And that brings us to the second series of storm areas on our economic weather map.

These are the nations who are our *friends politically* and our *rivals economically*. They are the nations who are our markets abroad, which by the inexorable laws of trade makes us a market for their products . . . a market which they have been hitting hard.

Admittedly, there is a certain amount of irony in this latter situation, since American aid played a prominent part in setting these countries back on their feet after World War II.

But long gone are the days when Thomas Paine could write: "Not a place upon earth might be so happy as America. Her situation is remote from all the wrangling world, and she has nothing to do but trade with them." *In a world of guided missiles, isolationist policies are completely obsolete.*

We must face up to the fact that any nation strong enough to help us militarily must also be strong enough to compete with us economically.

The only answer to this competitive dilemma is to expand the world market. What we need is not a bigger piece of the pie, but a bigger pie.

For some time, and particularly in recent months, we have been painfully aware that the U.S. is in an adverse position on the international balance of payments. In 1960, the net gold outflow from our country was somewhere in the alarming neighborhood of $3 1/2 to 4 billion, owing in major part to our loans, grants and military expenditures overseas. Clearly, we have two choices: either decrease our expenditures abroad, weakening our political-military position, or increase our trade surplus.

In the latter half of 1960, we were exporting goods at the annual rate of $20 billion, about a 22 per cent increase over 1959. If we can increase our export trade by that much more, we could wipe out the balance of payments deficit without reducing current import levels, *and that is an entirely practical goal.*

It is frequently alleged that high wage rates have priced us out of world markets, and there are some discouraging statistics available on this score. In the major countries of Western Europe, for example, wages in manufacturing industries range from $1.08 an hour in Sweden to 57¢ in The Netherlands, compared with $2.68 in the U.S. In Japan, the average is far lower. Obviously, our export products from the United States which have a high labor content pose special problems for us.

Some quarters have been quick to demand governmental tariff action to protect American's position in the world economy. This type of thinking can only be called economic isolationism . . . as out-dated as the political variety. Tariffs are like a golfer's handicap -- an admission that he can't shoot par and a device to give everybody a chance to win. This is a commendable concept for a club tournament, but I've never seen it proposed for the Olympic games. Instead of confessing competitive weakness, the United States must meet competition by finding ways of expanding its trade overseas.

Government action is no substitute for the vitality and initiative of private enterprise. The import-export status of products and industries has never been static, and we should never try to make it so by government regulation.

There will be casualties. There are casualties now, everyday, caused by domestic competition . . . but we don't wring our hands and say "There ought to be a law". This is the way the competitive discipline works to create maximum benefits for customers . . . and that includes all of us.

Let's not try to solve our problems by tariff action. When we build a fence, we must consider what we are fencing in as well as what we are fencing out. If we fence out imports, we are going to fence in our own exports, for it is an unpleasant fact that the world no longer depends upon our products as much as it did a few years ago.

I said a few moments ago that another 20 per cent increase over and above any natural increment is a practical goal. I have two major reasons for this optimism.

First, there is the interesting fact that the 1960 export growth was due almost entirely to the European economic boom -- the same boom which put them into competition with us on the world market. It has created labor shortages, rising prices, and slower deliveries . . . does that sound familiar? . . . all of which have encouraged the purchase of U.S. goods and made them more competitive.

Furthermore, it is estimated that as much as 15 per cent of our 1960 trade surplus can be attributed to trade liberalization in Western Europe, where many countries have modified or abolished import restrictions against our goods . . . a trend which, *unless we ourselves take retrogressive action, can be expected to continue*. Finally, the European boom may very well spill over into other countries, creating more foreign buying power for our products. It is particularly notable that Canada and Latin America, traditionally our major foreign customers, have been in a slump which did not enable them to contribute to the 1960 increase in U.S. exports. If their economies can be persuaded to pick up, we would have a running start toward another $4 billion increase in our trade surplus.

My second reason for believing that we can more than hold our own against foreign competition lies in the great scope of diversification in American research and development, which can provide products in export demand and create the jobs we must have. In the decade of the Fifties America invested 69 billion dollars in basic and applied research. This has generated a flood of new products. In 1960, the total expenditure for research and development in the United States was approximately 13 billion dollars, which is projected to 27 billion dollars by 1970. This includes the research effort for the defense program which is knocking on every closed technological door in every branch of science. This research is contributing to the economic defense of the United States as well as to our security program.

Our answer to trade deficits must be to capitalize fully on this tremendous technological effort and capability. We must aggressively export what might be termed Model II products while the importing territories are in a Model I phase. As they move into a Model II position, we must be in Model III.

U. S. companies not now exporting to Europe or producing there may find the continent increasingly attractive as a production and distribution base. Prime candidates are those products which cannot be manufactured here and sold competitively and profitably in that market. Importing from ourselves also protects our competitive position on those products in the U. S. market against similar foreign exports.

Such transfer of work overseas in order to meet foreign competition both there and here does not mean we are merely transferring American jobs. Such transfers can create more jobs here at home. Let me give you a specific example with which I happen to be familiar: Burroughs Corporation.

After the Second World War, you will remember, most of the world had little dollar exchange and United States exports were severely handicapped by licenses and quotas. At that time, Burroughs had only one foreign manufacturing facility -- a small plant in England, established before the turn of the century.

In 1949, we created a new plant in Scotland and transferred one major product -- the calculator -- for world production. This released facilities for us to use in going into production on new products in the United States, generating additional jobs here. At the same time, by purchasing calculators from our Britain plant for dollars, we created the exchange necessary to ship U.S.-made parts for other products into Britain for finishing and assembling there. This program permitted us to export these many products on a Sterling basis to most of the soft currency areas of the world. More plants in Britain, France and Brazil have since been added, and our international business has multiplied rapidly.

My point is this: Between January 1, 1950, and January 1, 1960, we created 5,500 additional jobs overseas. *In that same time, for every job added abroad, we created more than three jobs in our U.S. operations*.

We do not think we could have approached that rate of domestic growth had we confined ourselves to our own shores. That's why we at Burroughs are convinced that investing abroad is also investing at home . . . why exporting certain production is also importing domestic expansion and jobs for American workers.

And now that I have brought us back home, let's look more closely at the economic weather that is building up here.

In spite of the seeming prosperity reflected in the sales charts, narrow profit margins and limited surplus for reinvestment have been and are distinctive features of the American

economic system in recent years. Our politics have been so strife-torn in the last thirty years that around profit's head has swirled a storm of controversy. "Profit" has become a dirty word for many misguided, if well-intended, people who would somehow contrive to reduce profit from business and yet have something left which is neither socialism nor communism.

We can no more take away adequate profit and have left free enterprise than we can take away the people's right to vote and have left democracy. Profit is the wage of enterprise, and these wages have been going down at the same time that the cost of living index for business has been going up.

The cruel truth is that our national income has risen by better than 120 per cent in the postwar era, but corporate profits have increased by only 23 per cent. In 1947, corporate profits were 9.2 per cent of our national income; by 1951, profits were down to 7 per cent, and in recent years they have fallen to 6 per cent or below. *This clearly defined downward trend should be of major concern to statesmen as well as industrialists in this perilous time when our industrial expansion and Gross National Product growth is more necessary than ever before.*

One of the big jobs before us is to scrub the dirt off the word "profit". We must re-acquaint the American public with the difference between "making a profit" and "profiteering"; remind and convince them that profit does not accumulate in corporate strong-boxes but is paid out continually for the use and improvement of tools.

Everyone should understand that the American system of free enterprise is a profit system, and that from these profits and only from them do we get job security, our high standard of living and the initiative of action which has placed the United States in its position of world leadership.

Economic illiteracy is probably the greatest single threat America must face.

I have been speaking for the most part about the export market. Our biggest market, of course, is right here at home, and certainly this one cannot be neglected.

Census figures show that a baby is being born somewhere in the United States every 7 1/2 seconds. This means that since I started speaking to you, about 200 new customers have been added to tomorrow's market; in this one year of 1961, about 4 million such new customers will be born.

To give an idea of what this means to the future economy it has been estimated that this one year's "crop" of babies will buy, among many other things, in their lifetimes a billion pairs of shoes, 25 billion pounds of beef, 63 million suits and dresses, 11 million new cars, 91 billion gallons of gasoline, 200 million tons of steel, 50 billion quarts of milk, 6 1/2 million refrigerators, a million new houses, 65 million tons of paper.

As I said at the outset, we will have no difficulty in producing enough goods for this growing population of ours with enough left over to sell the rest of the world all it will buy.

Foreign competition, whether friendly or hostile; dwindling profit margins; economic stagnation: all these threats can be met in only one way -- by adequate growth on the revenue front. We have arrived at the time when marketing management must establish new pars for the course.

Most of us will agree that we are on the verge of a breakthrough into a wholly new level of economic activity, world-wide in scope, intensive in penetration. The future years offer tremendous opportunity -- and I want to emphasize this -- for failure as well as for success. One of our greatest freedoms in America is our complete freedom to fail. That freedom permits us to stick out our chin; to go out on a limb; to take a chance. And we get the reward for doing so if we are right. The worst mistake we can make is to fail to exercise this freedom to fail. Inaction is the surest road to failure.

The sternest challenge in the history of business lies ahead. We have no alternative to success because the failure of free enterprise would mean the failure of all that America stands for. Let us draw on our experience, blueprint our problems and plans, activate our programs, and move forward toward the sunny clime of full and lasting prosperity.

If we don't, we are likely to find ourselves in an economic climate which resembles the weather of one of the early western mining towns: "Eleven months of winter, and one month mighty late in the fall."

BUDGETING FOR RESEARCH AND ENGINEERING COSTS

by JOHN C. DEAN
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B.S. in Business Administration
Boston University - 1948

C.P.A. Massachusetts - 1951

BUDGETING FOR RESEARCH AND ENGINEERING COSTS

By JOHN C. DEAN

Manager, Budget Analysis Department, Ford Motor Company

Definitions
- Research
- Product Engineering
  - Advanced
  - Design and Development

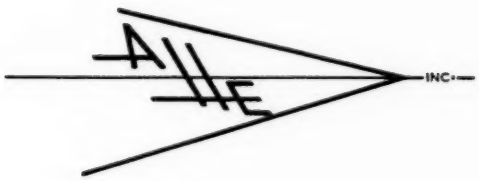
Management Role
- Long-Range Planning and Policy
- Establishment of Control
  - Assignment of Responsibility
  - Delegation of Authority
  - Periodic Review and Evaluations

Calendar Year Versus Lifetime Budgets

Development of Budgets
- Role of the Engineer
- Estimating
- Selection of Projects

Control and Reporting of Costs

Evaluation of Performance



NUMERICAL CONTROLS - TYPES AND FUNCTIONS

by **W. D. GEIST**
Director of Sales
BOEING APPLIED COMPUTING SERVICES
BOEING AIRPLANE COMPANY
WICHITA, KANSAS

Mr. Geist has been affiliated with Boeing for 19 years and has held various positions with the Company.

He was Chief Equipment Engineer from 1953 until May 1960 when he was appointed Director of Sales of the newly-formed Boeing Applied Computing Services.

NUMERICAL CONTROLS - TYPES & FUNCTIONS

By W. D. GEIST

Director of Sales, Boeing Applied Computing Services
Boeing Airplane Company

N/C IN THE field of manufacturing, as we know it today, falls within four classes. These four classes have been designated by the Aerospace Industries Association (AIA) as follows:

Class I: Tape Template Controlled
Class II: Cyclic Controlled
Class III: Point to Point
Class IV: Continuous Path

We are more concerned and involved with Classes III and IV today, but to be a little more specific on each class lets take a look at how they are applied.

Class I: Tape Template Controlled

This class is normally used on tape controlled riveters and can control the motion of the work piece or the motion of the riveting machine.

The tape can be made from various materials such as movie film, metal foil or metal strips and can be designed to control many functions.

In this class of N/C a hole is punched or drilled in the control template when a function of the machine is desired and normally these are a lineal function in regards to rivet spacing.

For an example if the rivet spacing is one inch apart the holes in the template are one inch apart.

The system that I am most familiar with is one which utilizes 35 Millimeter exposed film and contains 7 levels of information.

These seven levels control are:

Channel 1. Stop
Channel 2. Longitudinal right
Channel 3. Deep drop
Channel 4. Transverse in
Channel 5. Machine hold
Channel 6. Transverse out
Channel 7. Longitudinal left

Class II: Cyclic Controlled

This class is utilized on equipment that has a definite and set cycle of operation. An example of application for this class is in the field of stretch presses and welding equipment.

The first two classes are somewhat crude when compared to classes III and IV, in regards to control tolerances, but do suffice very well for their applications.

Class III: Point to Point

These are basically two classes that fall into the category of point to point. One is straight point to point without feed rate control and the other is point to point with feed rate control.

Without Feed Rate Control; This system is utilized on drilling equipment, punching equipment and boring equipment. In this application we are concerned with definite point locations and are not concerned with the method, rate control or close control of the path from one point to another.

With Feed Rate Control; This system is utilized on a variety of milling and turning equipment.

With these systems we are concerned with definite point locations, but also we want to control the method, rate, and close tolerance of travel between two designated points.

Class IV: Continuous Path

Of all N/C systems this one is the most elaborate and complicated.

In continuous path work we are concerned with generating various shapes that are in essence not straight line functions.

These shapes can be two dimensional or three dimensional and can utilize 2, 3, 4, or 5 axis of machine motion to generate these shapes.

Continuous path systems are being utilized on a large variety of machine tools such as milling, turning, boring, forming and welding.

Now that I have briefly outlined what the various systems are and how they are applied, lets look at how they operate.

All N/C in operation today function from either tape of card input. The tape can be either magnetic or punched and the punched tape can be of various materials.

Most of the industry has standardized on a one inch wide 8 level punched tape. In an attempt to achieve standardization of punched tape, both in physical dimensions and character coding the Electronic Industries Association and the Aerospace Industries Association have proposed a standard one inch wide eight level tape. The levels are designated with the numeric value of 1, 2, 4, 8 and 9, and by "CH" for parity check, "X" for certain so-called "X" codes and "EL" for end of line.

The systems builders utilize these levels for various functions as applied to their specific requirements consequently there is no standardization between builders.

It is also felt by a large portion of the industry that now isn't the time to attempt to much standardization because N/C is still an infant and much refining is left to be accomplished. Being associated with the manufacturing industry and with numerically controlled machines, I am confronted with tape differences such as address system, tab sequential, Binary coded, Binary coded decimal and others.

All of these formats as applied to a specific machine or function operate very satisfactory.

The tab sequential and address systems are applied to point to point operations with and without feed rate control. In this application the X, Y and Z coordinates of a point location are entered in the tape format as specified by the systems builders along with any variation of auxiliary functions. This information is then read by the tape reader and translated into the required signals for machine operation. These signals can either control electric or hydraulic motors which in turn position the machine at the designated point as specified by the tape format. The auxiliary functions that I mentioned are many and varied but include such items as feed rate, spindle speed, turning the coolant off and on, specifying flood or mist coolant, table indexing, changing cutters, indexing spindles and any other special items that may be designed into the specific system.

In continuous path operations the most common tape format terms are Binary Coded and Binary Coded Decimal.

In both systems the X, Y, Z coordinates are expressed in the tape format as binary numbers.

In the binary system the numbers are read lengthwise of the tape and a punched hole represents "1" and the absence of a punch as a "0". The total value of the binary number means that the control system will send that number of impulses to the machine tool to be interpreted and translated into machine motion. For an example if the X motion on the tape is expressed as 1000 in a binary number the machine control system will receive 1000 impulses. If the control system has a resolution or value of .0002 of an inch per impulse then the machine would move 1000 X .0002 or .200 in the X motion.

In the binary coded decimal the tape format is read across the tape and is expressed in binary decimals. The end result of both formats are the same.

One thing I should clarify is that the programmer or the person who prepares the program manuscript does not have to be concerned with binary numbers. He prepares the X, Y & Z coordinates in Arabic numbers and the tape preparation equipment utilized, translates these arabic values into binary information.

In preparing a program manuscript the programmer is not concerned with the part configuration, but the path that the center line of the cutter must travel to reproduce the part configuration. Any part can be programmed by hand, but in most of the continuous path operations this becomes to laborious to even

think of. Therefore large general purpose computers are utilized to accomplish the vast amount of calculations required.

We at Boeing - Wichita have been in the N/C business as a user since 1956. We are presently operating machines that fall into classes I, III and IV. The greatest percentage of our machines fall into III and IV. Early in 1957 we discovered that to gain the greatest potential offered by N/C a computer program would be required. we formed a group of qualified personnel and set forth several objectives that were to be accomplished. Out of this effort came our computer program known in the industry as W.A.L.D.O. which stands for the Wichita Automatic Linear Data Output. At the present time we utilize W.A.L.D.O. for computing programs for all of our machines.

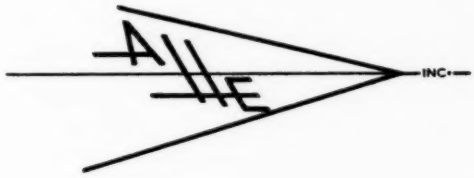
With the W.A.L.D.O. Language we are capable of programming any shape that can be expressed mathematically. The entire W.A.L.D.O. language consists of only 33 words. These words are a conjunction of words and are very easily learned by programmers. We are limited by the computers to 5 letters in these words. For a few examples:

1. CIR —— Circle
2. CONIC —— Conic
3. CURVE —— Curve
4. INCIR —— Inscribed Circle
5. FINT —— Far Intersection
6. NINT —— Near Intersection
7. TANPT —— Tangent Point
8. BNDRY —— Boundary
9. TRACO —— Transfer of Coordinates

A programmer using the W.A.L.D.O. System is not required to make advanced calculations. This is taken care of by the computer. The educational requirements for a programmer using the W.A.L.D.O. System is a high school graduate or equivalent.

Boeing - Wichita is utilizing N/C for producing all types of Air frame parts ranging from wing panels 36 inches X 76 feet down to very small items.

I will now show some slides of parts that we are producing and will point out how the various systems function to produce the various parts.



ADVANCED MATERIAL HANDLING TECHNIQUES

by STAFF OF CLARK EQUIPMENT COMPANY

CYRIL B. ROGERS, *Manager*

14 years in the aircraft industry of which 8 years were spent in structural analysis and design and 6 years in mechanical design. Bachelor of Aeronautical Engineering (BAE) University of Detroit. Worked with and directed the activities of engineering groups responsible for the development and design of fixed and rotary wing aircraft and their associated ground handling equipment, both for civilian and military use. 4 years a project structures engineer at Bell Aircraft Corporation. Has been responsible for preliminary structural design and structural research programs on missile airframes. Experienced in preparing specifications for military research programs. In charge of new product development for past 5 years. Registered Professional Engineer, State of Michigan.

GLEN R. JOHNSON, JR., *Marketing Manager*

18 years in materials handling industry. BS degree Business Administration, Ohio State University. Worked and directed activities of sales groups responsible for marketing industrial trucks and tractor equipment. Has been responsible for analyzing present and future markets, conceiving new methods and products for development. Served as consultant on materials handling, plant layout, cost controls to customers of the corporation. Has written numerous papers, reports, manuals, and portions of text books on materials handling. Guest lecturer at colleges and universities, numerous speaking assignments before National trade conventions and technical societies. He has intimate knowledge of many industries and government agencies. He has served as Salesman, National Accounts Representative, Assistant to the Vice President, Assistant Regional Manager, Product Manager, Director of Sales Training, and Director of Materials handling Development Center.

FRANCIS (FRANK) M. DOBBERTIEN, *Staff Engineer*

6 years experience in Mechanical Design and Contracts Administration. Sphere of experience includes applications of Thermodynamic, Aerodynamic, Heat-Transfer, Hydraulic, Pneumatic and Stress Analysis Theory to the design of vehicles, power plants, dies, and electromechanical actuators. Familiar with Government contracts and specifications. Responsible for all engineering calculations performed on the Univac Digital File Computer Model 1. Qualified programmer and operator. Education consists of 2-1/2 years of Liberal Arts and 3-1/2 years of Engineering. Degree - BSAE from the University of Colorado.

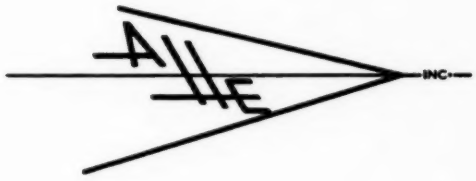
ADVANCED MATERIAL HANDLING TECHNIQUES

By CYRIL B. ROGERS, GLEN R. JOHNSON, FRANCIS M. DOBBERTIEN

Clark Equipment Company

THE SESSION will present new concepts and techniques of handling material and people. The discussion will be illustrated by photo slides and/or scaled models. These areas of interest will be covered:

1. Latest methods of freight container handling.
2. A new low cost means of moving materials between fixed points.
3. A new vehicle concept for travel.



BUDGETARY CONTROLS OF DIRECT AND INDIRECT LABOR

by **JOHN M. McBRIDE**
Assistant Controller
FORD MOTOR COMPANY

Mr. McBride came to Ford Motor Co. in 1955 to the Budget Analysis Department; later he became manager of Parts and Dealer Analysis. He then became manager of the Budget Analysis Department. Recently he was promoted to his present position of Assistant Controller.

Mr. McBride attended the University of Chicago where he received his M.B.A. and Ph.B.

BUDGETARY CONTROLS OF DIRECT AND INDIRECT LABOR

By JOHN F. McBRIDE

Assistant Controller, Ford Motor Company

BUDGETS for the control of direct and indirect labor, like all of our controls at Ford, are designed to influence management at all levels to act in the best interests of the Company and its stockholders. To achieve this objective, a control system must be understood by the men who will use it, it must be accepted as an appropriate measuring technique, and, most importantly, it must be effective in improving profits.

To facilitate the application of these controls throughout our organization, we have adopted standardized methods of planning, processing, accounting, and reporting. When we discuss manufacturing cost, direct labor, or indirect labor in various plants and divisions, therefore, we know exactly the types of expenses involved and the methods used to accumulate costs. We attempt to introduce this "standard" approach, however, without diminishing the creative effort of people in individual operations.

The most effective labor control in our Company, and the one most directly involving industrial engineering techniques, is the direct labor standard. This standard is a normal step in the development of our manufacturing planning and production system. After it has been decided to manufacture a part, our engineers plan the processing of the part over machines with known production capacity. Work standards engineers establish the exact time in minutes for each operation of machining, grinding, and polishing, for example, on the processing sheets. The processing time for all parts not only becomes a guide for machine layout and labor force assignment and a matter of record for machine loading, but also a basis for the control of labor input during the actual manufacture of the part.

Wherever possible, however, we have applied the direct labor standard approach in areas that might traditionally be characterized as "indirect labor" (e.g., shipping and material handling functions and certain maintenance operations). About 40 percent of the total labor in our manufacturing operations lends itself to controls by these "processed standards". For the remaining labor, it has been necessary to use controls that are less definitive. The development of new control techniques in these indirect labor areas offers a major opportunity for creative effort by industrial engineers.

In developing standards for these areas, we use a number of different factors to evaluate indirect labor requirements. Shipping and material handling labor may be related to tons of materials handled; sweepers and cleaners are related to floor space. Wherever possible, we identify a specific factor that can be used as a guide in controlling the employment of servicing labor. As you might have concluded, the processed standard and servicing labor control are largely established and administered by the plant and division staffs.

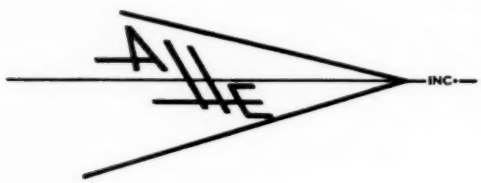
The effectiveness of this control has been increased by comparing cost levels in individual manufacturing plants and establishing, as an informal standard, the best cost relationship for each classification of indirect labor. Where we have been able to develop these operational comparisons in our assembly plants, stamping plants, or engine lines, we have made remarkable progress in improving costs. These "best ball" comparisons are especially valuable in many of the indirect cost areas where cost levels are primarily a matter of judgment rather than specific workload analysis. There are certain cost areas, too, where the most effective control system is a periodic directive from the appropriate level of management to re-examine costs and effect a reduction.

Under our system, budgets are prepared for

an area directly within the responsibility of a supervisor, thus a foreman would be concerned with production, machine repair, die-set and material handling costs but not with general plant maintenance or administrative costs, whereas, the plant manager's budget would include all these areas.

No matter how effectively standards are developed, however, there is no limit to human ingenuity and no substitute for competition. Given a fairly complex production job, I am convinced that a lower cost level will be achieved when three or four good supervisors independently try to beat the cost levels included in the original processing. The contributions of each man are then incorporated to produce an optimum cost. The ingenuity of our manufacturing people has convinced me that there is no "ideal" cost level for an operation that can be established as the ultimate target.

In any general discussion of the control of labor costs, however, I feel it is always appropriate to inject a note of caution. The primary method to reduce labor costs is through additional capital investment; as a result, actions to result in improved direct and indirect labor costs should be accompanied by a careful examination of the fixed cost and profit associated with a capital expenditure proposal. For this reason, budgetary control of direct and indirect labor costs at Ford is only one major component of an overall financial control system based on divisional profits and return on assets. With this system, we can insure that improvements in labor costs contribute their full share to the profitable operation of the company.



INDUSTRIAL ENGINEERING FUNCTIONS IN INTEGRATING NUMERICAL CONTROL

by JOHN P. BUNCE
Manager, Industrial Engineering
KEARNEY & TRECKER CORPORATION

Mr. Bunce earned his B.M.E. at Marquette College of Engineering.

His practical experience started at Kearney & Trecker as a co-op student. He moved rapidly through a number of positions such as Draftsman, E.I. Engineer, Ass't Advertising Manager, Sales Engineer, Ass't. Sales Office Manager, Customer Application Engineer, Control Manager - S.M.D., Ass't. Works Manager to his present position as Manager of Industrial Engineering and Quality Control.

Mr. Bunce is a member of AIIE.

INDUSTRIAL ENGINEERING FUNCTIONS IN INTEGRATING NUMERICAL CONTROL

By J. P. BUNCE

Manager, Industrial Engineering, Kearny & Trecker Corporation

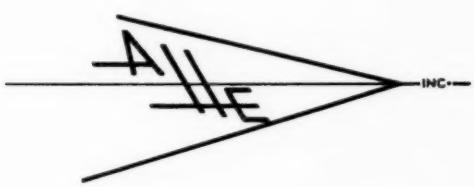
I. Utilization of Facilities
   - A. Current equipment
   - B. Potential new equipment

II. Potential Product Selection
   - A. Current product line components
   - B. New product line components
      1. Machining operations required
      2. Machine capacity required
      3. Configuration

III. Industrial Engineering Organization
   - A. Personnel
      1. Programming
      2. Tool design
      3. Technicians
   - B. Programming
   - C. Tool design
      1. Fixtures
      2. Perishable tools
      3. Tapes
   - D. Proveout of complete operation

IV. Numerical Control Department Organization
   - A. Preparatory machining operations
   - B. Tool setting
   - C. Milwaukee-Matic operations
   - D. Cleanup machine operations
   - E. Preventive maintenance

V. Advantages of Numerical Control Machine Operations
   - A. Tooling
   - B. Following prescribed methods
   - C. Quality
   - D. Inventory
   - E. Lead time
   - F. Loading and scheduling
   - G. Material handling
   - H. Inspection



ESTIMATING ANALYSIS-COST ENGINEERING APPROACH

by JEROME PEARLMAN
MANAGEMENT CONTROL SYSTEMS, INC;

Responsible for implementing the PERT/PEP technique at the General Electric Company during 1959 and 1960, Mr. Pearlman brings a broad background in the development and implementation of management control systems to operating problems. As Supervisor of Quality Control Engineering at Philco Corporation, he was responsible for designing and implementing statistical quality control procedures for improved management action. His work also entailed, in 1954, the application of work sampling techniques to secretarial operations—one of the earliest uses of this tool. At General Electric, he developed the field quality control and reliability program for the Atlas guidance. His work as Manager, Engineering Resources Planning and Analysis took him across the cost, resources, schedule and performance spectrum. His functions have included business planning, resource utilization plans, cost estimating techniques, economic analyses and a host of related programs. Since early 1961, he has been associated with Management Control Systems, Inc.

Mr. Pearlman holds a B.S. in Marketing and Statistics from Temple University. He has membership in Alpha Delta Sigma, national honorary marketing fraternity, and has also authored numerous articles in the field of management control systems.

ESTIMATING ANALYSIS -- THE COST ENGINEERING APPROACH

By JEROME PEARLMAN

Management Control Systems, Inc., Cambridge, Massachusetts

AS IS customary when a title as ambiguous as this one is used, definitions must first be proffered. We will define the term "estimating analysis" as the usual practice of estimating cost or price. Please note that the phrase is "cost or price." You, I am sure, recognize that quite often there can be a random difference between the two numbers.

The cost engineering approach to estimating analysis will involve the application of the principles of mathematics or statistics to the development of cost, and ultimately price. A concept will be proposed which already has proved somewhat successful for estimating the costs of aircraft and aircraft engines. Engineering generally is defined as the application of known principles of science to the development of products. Mechanical engineering

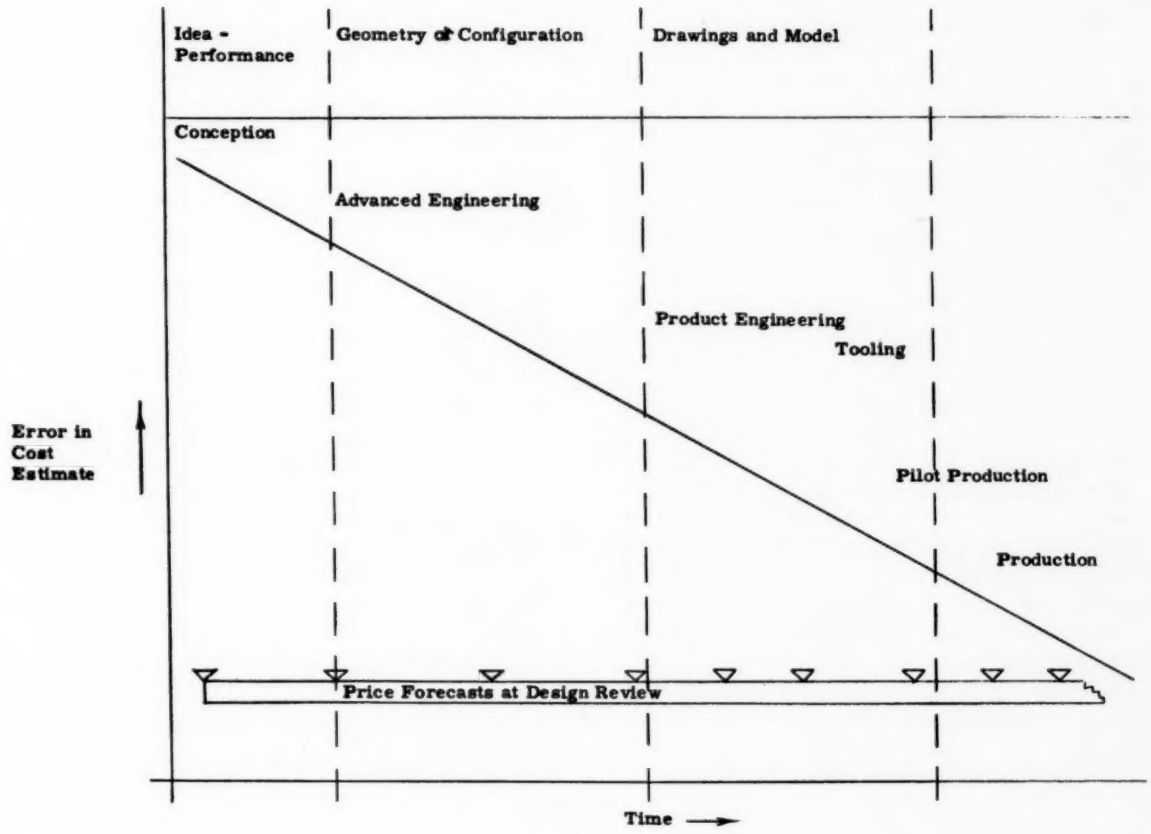


Fig. 1

involves products which are basically mechanical or moving. *Cost engineering will involve the application of the known principles of science to the creation of a cost methodology for manufacturer products.*

A PRODUCT LIFE CYCLE

Let us examine the customary life cycle of a product as illustrated in Figure 1. The purpose of this examination is to establish for this discussion a reasonable idea of how much information about the product we possess at various stages in the life cycle. It does not matter whether one stage of the process overlaps another or whether one stage of the process follows another.

Primarily the life cycle of a product starts when an idea is generated, either within the organization or through the market. This idea might be created out of a research function, from a production worker, or could very well have been generated from customer inquiries.

The first stage in handling this idea is putting it through an advanced engineering function where the concept will be brought to the point of showing that the product idea is feasible. This stage normally does not involve styling, packaging or any other features except performance. If feasibility is demonstrated, then the product is moved into a product engineering stage.

It is at this time that the design is prepared for production. Features of styling and packaging are also developed. At the end of this stage normally a set of drawings or specifications are released to the shop. For all intents and purposes the *first* design freeze is established at this point.

Tooling, gauges, test equipment and other similar components are designed as soon as sufficient product information is available. Normally, drawings are required before these accessories can be designed.

Whether a formal period entitled pilot production actually exists is unimportant. The slow build-up of production quantities indicates some pilot production since you know how many design changes enter the process at time time.

ESTABLISHING THE PRICE - THE CLASSICAL APPROACH

The axes of Figure 1 represent time on the abscissa and cost estimating error on the ordinate. Effectively, then, the error in cost estimates decreases as time elapses for as time elapses more is known about the product.

Now the problem is - when can a selling price be established on the product if we assume that this selling price does have some relationship to the cost of the design and of production? In many industrial organizations, cost or price is never established when the idea is first conceived. At the point of feasibility it is possible to establish some basic price although the margin of error is large. When the design is frozen--that is, when drawings are available--is the point in time when a price is most often established. This price is based specifically upon a concept and production design which the engineering function has evolved. Material lists are available and priced in detail. The Industrial Engineering function evolves process sheets so that direct labor can be priced in detail.

Occasionally during production it is found that this price is wrong because certain elements have been overlooked in the design. Another problem which comes to mind is what happens if the design is actually too much for the need. The expression used in the electronics industry is "design a Cadillac for the application of a Ford".

If a realistic price can be established only after the design is frozen and a set of drawings and specifications developed, then a great deal of energy and money has been expended to perform potentially useless engineering. It is not only the fact that useless engineering has cost money, but, more important, it has wasted resources. The creative people could very well have been working in an area that might have come to fruition.

THE PROBLEM

I am sure you are now aware that the problem I would like to pose is that price or cost is developed too late in the life cycle. Present

methods of pricing from detailed drawings and detailed bills of material is too cumbersome. Under the present technique, the potential loss of creative time is by no means small. The most crucial decision made by a management is which product to pursue vigorously. With price becoming so important, a sound decision must be made early in the life cycle of the product.

THE FIRST SOLUTION - COST STRUCTURING

It is the responsibility of the Cost Engineering function to solve this problem. To do so requires a dual approach in order to encompass the total engineering cycle from conception through pilot production.

The first approach is that of a challenging plan. Product and advanced engineers can and will create to order. They survive and prosper through ingenuity. Hence, let us use their ingenuity to design a product which will meet both a set of performance specifications and a price specification. In other words, when an operational requirement is established such as a four-passenger automobile capable of a top velocity of eighty-five miles per hour, a price specification *must* also be established. In the example just cited, supposing the price were established at $1,350, f.o.b. Detroit. A product which cannot meet the price set by the market is a useless development for it serves to glamorize an office or laboratory, not a treasury.

How can this be done? I submit that it is a requirement that the cost engineering function apply known principles of statistics to the development of mathematical relationships for price and performance. These estimating formulas would be based upon an arrangement where cost or price is a function of performance or operating specifications. Again, this

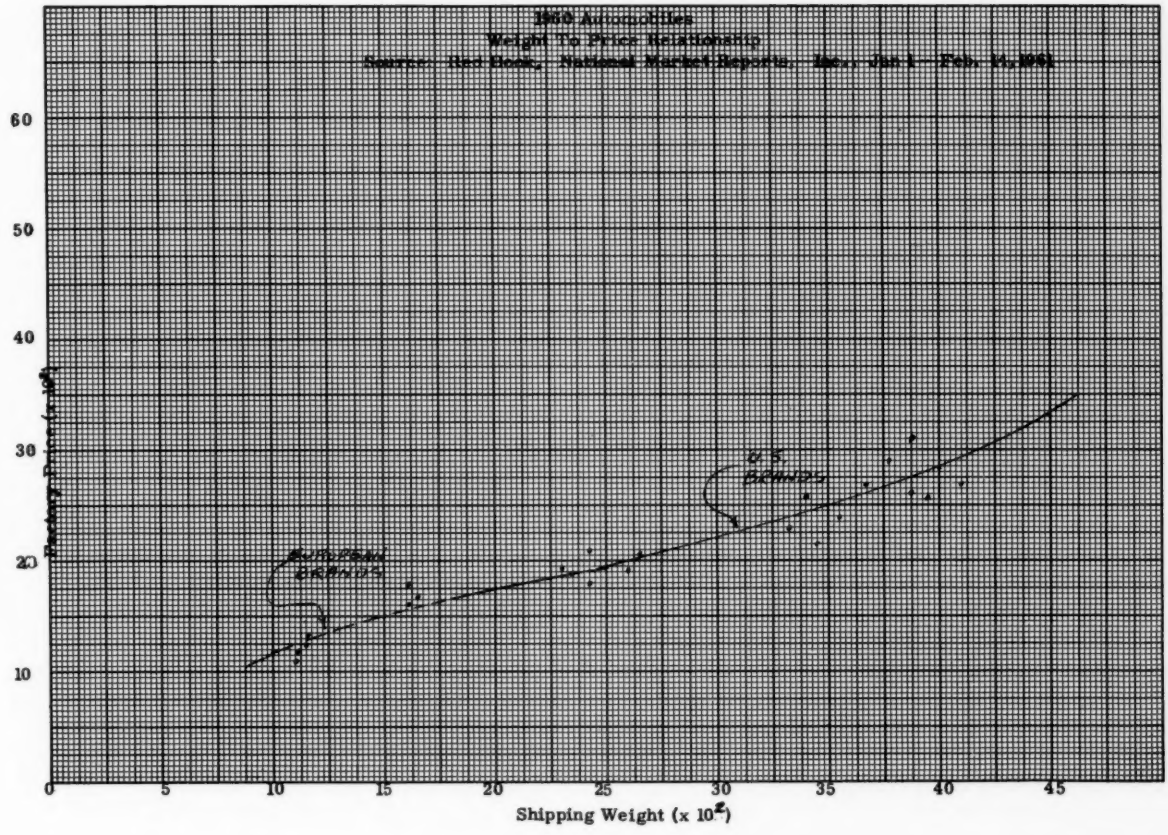


Fig. 2

has been successfully performed in the aircraft industry where cost or price is directly related to the weight of an airplane and to the velocity of the airplane. In the field of Jet aircraft engines the relationships are quite valid for velocity, acceleration, and thrust.

Let me illustrate with an example with which some of you may be familiar. Since we are in Detroit, it is reasonable to use the automobile as an example. Furthermore, complaints about the price of automobiles appear regularly in the press.

Figure 2 is a scattergram where the cost of the automobile is related to the total gross weight. The source for this information is the Automobile Redbook. You can see that a very nice straight line is obtained. Therefore, if it is established that a new automobile is to be put on the market which will weigh 3300 pounds, it becomes obvious that the price will be approximately $2500.

I would like to explain that the statistics are very rough and the sample, although of reasonable size, does have four points excluded because they are intuitively extreme values. The sample was chosen from the lowest price models in each major brand. The gross weights are for these models. Hence, there is a mixture of six-cylinder and eight-cylinder models. Furthermore, I am absolutely uncertain about the scientific relationship in this example. The apparent correlation may be spurious. This is only for illustration, using data that are readily available.

The hue and cry in today's economy is the decreasing export business and the increasing internal competition from imports. Within the last month I believe the *Wall Street Journal* has had at least one article every day describing how poorly the United States is doing in the foreign market. The article always states that we cannot compete with foreign-made merchandise because our prices are much higher.

Let us now examine Figure 2 with the addition of six points representing the price and weight of six of the most popular European vehicles. The price data are port of entry, East Coast.

It would seem on the surface, when studying Figure 2 that despite higher labor rates in the United States, the price to weight relationship is quite good. Apparently the Europeans do not make a cheaper auto -- they make a different auto. The design is obviously quite different, if weight is a crucial design criterion.

Has the United States ever been able to compete with foreign-made merchandise on a price basis? The answer is no. Why then in the past have we so successfully competed in the foreign market? We have done so by innovation, by having high quality merchandise, and something new all the time.

What about wheel base to price relationship? This is not quite so good, but again the example is cited because the data are readily available.

Let us now return to the original point. Our cost engineering need is for a new technique to assist management and the product engineer. The cost engineer must return to the womb of his academic training and embrace again the concepts of mathematics. A research or study program is needed to develop formulas which demonstrate cost or price as related to performance or design objectives.

Supposing this were accomplished by the cost engineer, and supposing he used now a complex linear function equation such as that below:

$$\text{Price} = \mu + aX_1\ bX_2 + cX_3 + dX_1X_3 \ldots\ldots nX_i$$

μ = a constant
X_1 = weight
X_2 = wheel base
X_3 = maximum speed

You can see that there is a simulation capability involving the variables - weight, wheel base, maximum speed, horsepower per weight ratio, engine weight, seating capacity, compression ratio, etc. This kind of functional arrangement would permit a designer who is told that his price must be $1750 to trade off certain operating characteristics about the automobile. It would also create the need for innovation. It is obvious that a 3,000-pound automobile for this kind of money, produced in the United States, would require a radically new design. The challenge for creativity is present and the tools to help are also available.

The formula concept covers the problem of cost planning or price planning. Another way of stating the same thing is that the design will be structured by the cost rather than the reverse. Cost then becomes a specification rather than an afterthought.

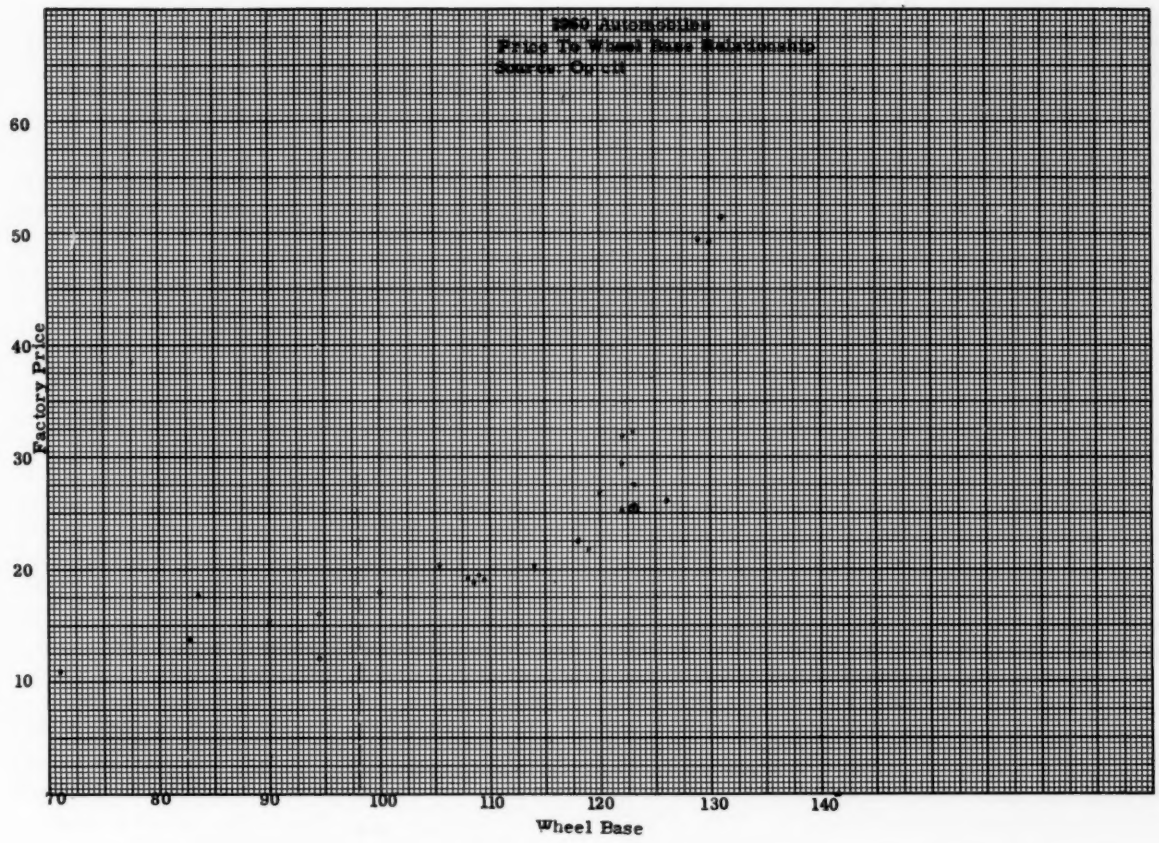


Fig. 3

THE SECOND SOLUTION - COST CONTROL

Will the design or product during its development and design cycle meet the performance and cost specifications? Is there a means to help ensure meeting the cost specification?

Some organizations or enterprises have adopted the "design review" as a regular procedure for evaluating engineering conformance to performance requirements. This can be construed as Quality Control of the design process.

I submit that to close the loop of plan and then control, the design review process should be modified. If design review is not a formal requirement of the engineering department, it should be. If it is, or when it is, the procedure should allow for a continuous price analysis using the devised formulas. Furthermore, the concepts of value analysis can then be introduced during the conceptual and advanced engineering portions of the product life cycle. In this way, value analysis can take on some meaning rather than merely interfere with a smooth production program.

In the value analysis program a given design is normally made cheaper. Sometimes the price is reduced; sometimes the organization merely pockets the extra profit. The typical approach is "blast and refine". For example, if a particular upholstery in an automobile is being made from nylon and wool, the value analyst asks - can an equivalent quality be made from cotton, with an attendant cost saving of perhaps $15.00 per auto? In looking at the moving parts, he might ask whether a particular gear being made from stainless steel could not just as easily be made from some other metal which is cheaper. The value analysis, therefore, over a long term could perhaps reduce the price of the auto or

the cost of producing the auto by 10 percent. But, it alone does not contribute to meeting the threat of foreign competition.

Suggestion programs and other similar cost-reduction programs are in the same category with the present applications of value analysis. These programs are nice, but they are almost invariably after the fact.

However, the formal design review of performance can be modified to allow a measure of control by the cost engineer. The formulas can predict the product price. Early introduction of value engineering should offer an even better value.

THE IMPLICATIONS

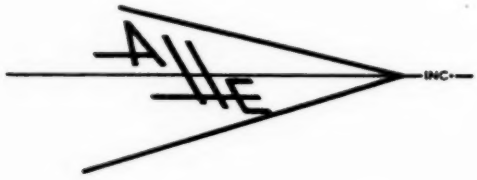
To meet the challenge, I must reiterate that the cost engineer must begin the application of science to his job. He must be not only skilled in the design and production functions, which are within his particular functional area, but he must also become familiar with the principles of statistical analysis. He must be familiar so that he can develop the mathematical models and relationships which we have briefly illustrated. Then, he will be capable of analyzing an idea when initially generated to determine how the price may affect the market demand. The approach, developed from a systems point of view, can do a lot to strengthen the ability of the corporation to differentiate between products which they wish to pursue vigorously and those which are scientifically nice but have a negligible market value.

The cost engineer would now begin to use engineering. He could contribute to the development and design and marketing of the product and thereby make a direct engineering contribution to the enterprise.

SUMMARY

The principles which we have briefly described are used to generate a mathematical model capable of relating performance to cost. By this approach challenging performance and price specifications can be established for the design engineer. These challenging specifications will generate a product which is sufficient to meet the quality needs of the market and to meet the price requirements of the market. Control through a formal design review process during which the formulas and value engineering are applied will ensure the ultimate fulfillment of the specifications.

In these ways, the business enterprise pursues products with pay-off rather than products which cannot meet a price constraint. By the application of ingenuity we will be able to meet the threat of foreign competition without any reduction in our standard of living.



THE EFFECT OF FOREIGN COMPETITION ON UNITED STATES INDUSTRY

by JAMES H. GOSS
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James H. Goss is a vice president and group executive of the General Electric Company with over-all responsibility for the International Group, to which the Company's International General Electric Company Division is assigned. In this capacity he also acts on behalf of General Electric with respect to its interest in and relations with the Canadian General Electric Company, Ltd.

Mr. Goss was born in Paris, Arkansas, September 22, 1907. He is a graduate of the University of Arkansas (B.S.M.E.), and the Harvard Advanced Management Program.

Mr. Goss joined General Electric as a design engineer in West Lynn, Massachusetts in 1931. He moved to Schenectady, N. Y., in 1947, when he was appointed manager of engineering for the Company's Industrial Control Department.

In 1951 Mr. Goss returned to Lynn as assistant to the general division manager of the Small Apparatus Division. Later that year he became manager—manufacturing for the Company's Major Appliance Division in Louisville, Ky., and in 1953 he was appointed general manager of the Home Laundry Department, also in Louisville.

In 1955 Mr. Goss was named president—Canadian General Electric Company, Limited.

Mr. Goss was appointed Vice President and Group Executive for the Consumer Products Group in October, 1957. He assumed his present post in September, 1959.

THE EFFECT OF FOREIGN COMPETITION ON UNITED STATES INDUSTRY

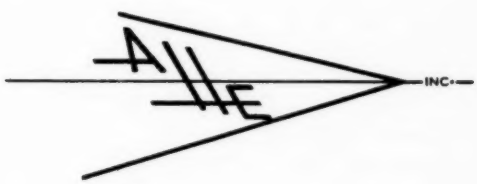
By J. H. GOSS

Vice-President and Group Executive, General Electric Company

A SUBJECT that is of real interest to both business and the public is the area of "Foreign Competition and Its Impact on United States Industry."

It is interesting to study the attitude of the public, the government, and labor unions of countries who have had to rely on exports as an important part of their national economy as, for example, Great Britain, Japan, Holland, Germany and Switzerland. In these countries it is quite evident that there is a harmonious and close working relationship between the government and business for the purpose of maintaining exports at a high level. This is also well understood by labor leaders and the members of the unions. This is in contrast with the degree of understanding of the same groups in our economy as to the importance of foreign trade.

With the distances across the world measured today in time rather than in miles, we are rapidly attaining a number of the aspects of a single economic system in the free world. The conflicts between this economic system and the communist countries will become of increasing importance in the decades ahead. Certainly the best economic defense of the west is a strong economic system based on free enterprise and a broader realization on the part of business men, government officials, and the public of the realities of this changing situation.



DEVELOPMENTS IN THE SIMULATION OF OPERATIONS USING DIGITAL COMPUTERS

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DEVELOPMENTS IN THE SIMULATION OF OPERATIONS USING DIGITAL COMPUTERS

By JOHN FRANCIS LUBIN

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THE NUMBER of uses for electronic digital computers has considerably increased in recent years; no longer are they regarded merely as very fast substitutes for clerks or "super slide rules." Social scientists, operations researchers, and industrial engineers know that these machines are research tools of the highest value for them and are not to be limited to data processing and problems in physical science. One of the most rapid of these increases has been in digital computer simulation of operational problems. Much of this work has been directed to research on development of various theories with general rather than specific implications, such as the nature of decision making in business firms, simulation of the United States economy and study of cognitive processes. Of more immediate concern, however, are the digital simulations of real firms and actual operating situations: production control, inventory systems, queuing problems, maintenance scheduling, materials-handling installations, evaluation of plant layout, and so on.

Both published and unpublished reports indicate clearly that digital computers are being used quite extensively to simulate many different discrete flow systems.(1) Indeed, it appears that there is a *very* great deal of work being done in this area but, unfortunately, little of substance has been made available. There are rumors of quite sophisticated simulators for production scheduling, inventory control, and materials-handling systems and other applications. These were developed for particular uses by particular firms; they cost time and money, and the model and computer programs used represent the configuration of specific operations in a plant or firm. In these circumstances, many firms have apparently decided to keep the details of their simulators secret. This has had the obvious effect of making the extent of computer simulation for the analysis of business operations seem to be less than it actually is.(2) It means that knowledge is not disseminated. It means that a potentially valuable technique is not being employed in the most effective way.

Many of these applications are directly related to industrial engineering. Both the number and relevance of such applications in the future seem certain to increase in spite of the secrecy.(3) The following quotation from a report of a conference on the use of computers in engineering education is pertinent:

> BROWN: Isn't it possible to go too far with simulation? . . . Glass flowers for real ones illustrates this. If you're studying the simulated problem may you not miss some easy discoveries?
> HAMMING: In 1960 Bell Laboratories' experiments are 90% done in the lab and 10% on the computer. I believe that before the year 2000 Bell Laboratories' experiments will be 10% lab and 90% on the computer.
>
> Simulation on the computer is usually more fruitful, faster, cheaper. . . .
> GALLER: Often in comparing differences between the actual and simulated model, we can gain insight into what is yet to be explained in the actual case. Hence we can discover a great many things by simulation.
> EVANS: In industrial engineering we must simulate . . . we have no choice.(4)

THE CONCEPT OF "SIMULATION"

Simulation is now new. Many have suggested that the distinguishing characteristic of

human beings is an ability to create abstractions of reality: symbols and models, and an ability to analyze these models, almost always less complex than reality, in order to predict what the consequences of actions in the real world might be. In engineering, especially, there is a well established acceptance of the notion of model construction. Examples are legion: two and three-dimensional templets used in plant layout, activity and man-machine charts, Ohm's Law, electric utility network system analyzers, flow diagrams. Notice that the common feature is the concept of an analog whose characteristics in some respect are so like the original system that the performance of the analog can be used to predict the performance of the original. Thus, we have a "simulator," an imitation not necessarily of all the characteristics of the object system but of those which help us answer certain specific questions about the original. There is no requirement that the simulator be "realistic" or "complex:" there is no reason for the simulator to duplicate the original for the original is available for observation in all its realism and complexity. Indeed, complex representations or models very often are the result of lack of knowledge. With greater insight, bounds can be set, sub-units can be combined, and generalizations made that lead to simpler models.

The word "simulation," then, can be used in a broad sense. But it is usual to restrict its meaning further. We can experiment with an actual system by varying inputs and modifying internal characteristics. This can be impractical and sometimes impossible. Considerable progress has been made by using a mathematical model of the system, either deterministic or probabilistic, and analyzing the model, rather than the object it represents. Methods have been developed to find the state of the model, or the values of parameters, or the starting conditions which will produce output which will meet certain criteria. But what if the system is so complex that no analytical solution is yet available. Or suppose the inputs and characteristics of the system vary constantly and violently and further suppose the causes of those variations are not understood, then often no analytical methods are available.

In such cases, we can manipulate the model itself and predict from the results what might have happened under the same manipulation in the object system (which should be large enough and complex enough to justify this procedure). But we further limit ourselves to "digital" simulation: the numerical manipulation of models programmed on electronic digital computers for the purpose of studying large-scale systems and their performance. Analog computers are excluded from this presentation. In many cases, such analog devices are excellent simulators; this is especially true of cases in which a specific problem is to be manipulated many times with different parameter values. Such machines are simple, rugged, and relatively cheap. They tend to be special-purpose instruments, however, and they do have inherent limitations on accuracy.

EXAMPLES OF DIGITAL COMPUTER SIMULATION: MEANING FOR INDUSTRIAL ENGINEERING

Almost any of the technical industrial engineering functions can be simulated. There are simulators in existence for such diverse problems as determination of maintenance crew size, traffic scheduling, gasoline blending, facilities utilization, and manufacturing operations simulation (in both job-type and flow-type shops). Simulations can be used to analyze the effect of product mix variation on capacity, costs, or profits; to discover the crucial components in the operation of an enterprise; to improve production scheduling and dispatching; to test without disrupting operations the possible effect of new policies and procedures or of new facilities. Even such difficult problems as queuing networks with many service points and non-predictable arrival and service rates, and complex production line problems with feedback have been handled with digital simulation. Furthermore, simulation has been used to help analyze large-scale organizations as well as functional sub-units. The Rand Corporation Logistics Systems Laboratory developed models of the Air Force supply function involving certain activities of Headquarters USAF, Headquarters Air Material Command, air defense command bases, air material areas, maintenance, supply, factories, and repair facilities. One of the most ambitious and interesting large-scale

simulations is Dr. Guy Orcutt's "Decision-Unit Model and Simulation of the United States Economy." Possible applications seem limited only by the inventiveness and ingenuity of users. Hurni and Shubik of the General Electric Company go so far as to state:

> The trend of the future is such that given the present progress, in the next twenty years *most* businesses of the size of an average Department of the General Electric Company will possess a simulation of the business to be used for planning and anticipation at many levels.(5)

SIMULATION AS A "LABORATORY"

One of the most intriguing statements made in justification of simulation is that, because of this technique, at last management has a "laboratory" in which "experiments" can be conducted. An industrial engineer, as an example, no longer has to depend on his experience, intuition, deductive powers, rules of thumb, and luck when considering the possible effect of some particular change in the operation of a business enterprise.

Actual experimentation in enterprise is very difficult and often impossible. Costs are high. Often, such attempts are useless because of the great number of variables involved and the impossibility of trying another run "with all things equal except the factors under study." In such cases, simulation by computer is a possibility. Obviously, if analytic techniques are available, simulation is almost never advisable. But often the complexity of actual systems is so great that analysis is unavailing, and attempts at simplification and aggregation may produce results that are at best misleading.

STEPS IN DIGITAL SIMULATION OF DISCRETE FLOW SYSTEMS

The steps needed in developing a simulator of an operating unit in a business enterprise (such as a job-type machine shop) can be listed as follows:

1. Discovery and specification of the problem to be considered.
2. Data collection for the purpose of discovering relationships and for the development of the model.
3. Model construction. Represent the real system by a flow diagram. (Avoid useless detail; remember a good "simulator" is one which answers the specific problem posed and is not necessarily one which describes reality accurately.) Notice that the flow chart in operational simulation comes from a knowledge of the real physical system, not some mathematical statement of the phenomena.
4. Modify the model based on "field tests," deduction, and the results of simulation runs.)
5. Test the model by manual methods if possible. The computer may not be necessary at all.
6. Convert flow diagram to computer code.
7. Debug. See Step 4.
8. Experiment with the simulator. See Step 4. Attempt to design experiments with sufficient replication so that meaningful conclusions can be drawn from the output. Decide whether you are interested in transient or steady-state answers. Conduct runs accordingly.
9. Evaluate the results.

SOME QUESTIONS

1. Can you justify the cost of modeling and programing? This cost (plus debugging) always seems to be far greater than original (even padded) estimates. In almost every case, the logic and the model are more complex than anticipated. Also, the computer available, even the largest and newest, never seems to have enough storage for the modeler and programer.

2. Do you have realistic input data to put into the simulator? It is common to underestimate or ignore this problem. Often, such information is not available and obtaining it is usually expensive. Even when available, rarely is it in usable form.

3. How much confidence must you have in results of simulation? This will determine the number of runs necessary. Can you afford that many? Remember computer simulation is a sampling technique.

4. Should you design a special-purpose model and simulator which might well take

less time to develop and be more efficient in the use of computer time? How well can you bear the risk such a model soon may be obsolescent? If conditions or problems change, how easy must it be to change the simulator?

CAVEAT SIMULATOR

1. In too many simulations to date, the problems of experimental design and reduction of variance have not been considered. In any experiment (simulation included) it is intelligent to try to obtain as much information with as little cost, time, and effort as possible. Because high-speed computers are involved in simulation studies and the runs are fast and effortless, this reasonable premise is often neglected.

2. Do not neglect to provide for "field tests" to obtain the parameter values needed in a simulation model. Be careful about values obtained by deduction or from historical data. If the field tests indicate that the functional relationships in the model are incorrect, change them.

3. Results of simulations are often misused. Large-scale computer simulation often creates an illusion of omniscience, especially if the model is complex. Elaborate simulations have the illusion of reality. Furthermore, too many operating people either fear or revere THE COMPUTER: "if the computer says so, it must be so." The assumptions underlying the model are usually hidden; actual runs emphasize inputs and outputs, not the model. Elaborate simulations can produce masses of data; their analysis can be as difficult as that of the original problem. The large amount of data and their apparent accuracy are enticing and can dull the most critical faculty. After all, the print-out is real and impressive; who can doubt this most prolific of all methods? Doubt you must for this plethora can be useless. There are stories of elaborate computer simulations which produced results of apparent worth but which had some fundamental error in the model or computer coding. These cases emphasize the importance of simulator validation and suggest the difficulties of doing so. At the least, preliminary solutions are called for by using hand simulation, especially for relatively simple models, and by methods of gross approximation or analysis of degenerate cases. It is usual to include in the output a variable whose distribution is known.

4. Be certain that the problem cannot be handled analytically. If the number of variables is very large, perhaps they can be grouped or aggregated. Even if there is no analytic solution, simplify the model before simulation, if possible. (However, there are also real dangers in aggregation and in the use of so-called "expected-value" or "deterministic" models. The results can be in great error if the correct expected value is not used. The results can be quite misleading because of the loss of variation which is often a most significant characteristic of the object system.) Do not become so enthusiastic about simulation that you do not try to find analytic solutions for problems. The fact that simulation is so conceptually simple may be its greatest danger. Almost anyone can do it; unfortunately, almost anyone can do it badly.

SOME RECENT DEVELOPMENTS IN COMPUTER SIMULATION

The last three or four years have undoubtedly been the most productive of any similar period in the development of simulations of real operating systems. As has already been indicated, the restrictions coming from company proprietary interests made the evaluation of many of these changes difficult. Nevertheless, there are specific observations on the progress of computer simulation which can be made and which are summarized in the material which follows.

PROGRAMING

Much effort has gone into programing and coding of electronic digital computers for all applications, not only for simulation. The development of the various automatic coding systems in which a program is written in "problem-oriented" rather than "machine-oriented" language has nevertheless been most significant for the technique under consideration. It has meant a substantial reduction in the time from conception of a simulator to its actual use. Before, the development of a large-scale simulator might mean one, two, or even three years of work; the original need and purpose might not exist at the end of that

period of time. Automatic coding also has made much easier the task of changing the values of parameters in the model and the decision-rules being simulated. However, the most common operations in simulations of operational systems are logical operations; most of the compilers developed so far are not very powerful when used to these elements. An indication of things to come might well be illustrated by the "SIMCOM - The Simulator Compiler" of the Automatic Data Processing Facility, U.S. Army Electronic Proving Ground, Fort Huachuca, Arizona which is a special programing language and an associated compiler for *compiling* a fairly general-class of *simulators*. In another development, some of the newest compilers have very powerful, yet simple, ways of establishing closed subroutines, a most useful feature in simulation work.

FLEXIBILITY

Indeed, there has been a movement toward so-called general-purpose rather than special-purpose simulators. While they often are less efficient, once developed they can be used to create a program relatively quickly (within their limits) and can be changed easily to reflect changes in the object system in decision rules, and in parameter characteristics and relationships.(6) More and more, in addition, computer simulators are modular in form to facilitate coding and modification.

MACHINE IMPROVEMENTS

The availability of larger and faster electronic digital computers has meant that larger and more complex object systems can be simulated efficiently. In particular, the increase in internal high-speed memory size has made it possible to program with minimum effort, expense, and waste.

SENSITIVITY ANALYSIS

There has come an increasing awareness of one of the principal advantages of computer simulation: the ability to evaluate the effect on output of changes in parameters. This sensitivity of a system to changes in its components is valuable information and can be extremely useful in the management and design of the system; simulation is particularly appropriate for this work.

TIME METHODS

Computer simulation design has become more sophisticated. At first, most of the programs synchronized the events and their interactions in a model by a periodic review of the entire system ("master-clock" sequencing). In this method, inputs are updated and changes in state of components noted; flow is determined; output recorded. The review period must be short enough so that all events can be synchronized and so that there is no conflict between "simultaneous" events which interact. In many situations, *but not all* by any means, this method is wasteful of computer time because the usual state for any component is no change since the last review, but the program must search the entire system nevertheless.

Many simulators are now of the so-called "critical-event" or "trigger-event" or "minimum clock" type. After each event, the program determines the time of the next change of state of the component being examined. Periodic updating as such is not necessary because the program moves forward through simulated time to the next significant event wherever it occurs in the system. This shift can be short or long; for many kinds of simulation the over-all efficiency of critical-event simulators is greater than the master-clock type. Be that as it may, these considerations are indicative of the increase in "sophistication" now common in simulator design.

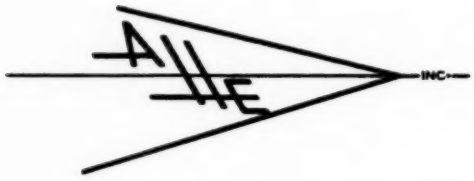
DESIGN OF COMPUTER SIMULATION EXPERIMENTS

Much effort has gone into variance reducing techniques. While it is true that simulation is almost always cheaper than experimentation in the real world, cost is an important consideration when computer time involves $200-$500 per hour. It was early recognized that it was not necessary, indeed usually impossible, to try every value of input, parameter, and decision-rule. By the use of iteration techniques and the concept of successive approximation, reasonable and practicable simulation experimentation is possible. In short, simulations of real systems involve a very great

number of interrelated variable; meaningful analysis may require a considerable range of possible values. The problem of experimental design is complicated by the fact that traditional methods of analysis of variance are of little assistance. Recognition of the difficulties in determining the number of runs needed and of their cost so that meaningful inferences can be made is now general, and the haphazard operation of a simulator is rare. Much needs to be done, however, in the development of theory of proper experimental design of experiments using computer simulations. It should be pointed out that sometimes we may be as interested in the fluctuations as in central tendency because fluctuations, in the real world, may be more significant in their effect and in their importance than changes in policy. Indeed, analysis often is very hard pressed to provide answers about the limits of variation of output. Computer simulation is particularly suited for this sort of study and provides non-steady-state information as well as steady-state solutions as a natural by-product.(7)

THE FUTURE

The doubts and warnings about computer simulation given here may have given the impression that simulation is so dangerous a tool that it should not be used. This is not true. There will be failures in the future, perhaps great fiascos. Nevertheless, there is little question that simulation is an important technique for management and perhaps an essential one. In a field such as industrial engineering, its potential cannot be ignored. It can provide new insights into already well-formulated problems and be very useful in improving the models of not-so-well-formulated problems. The results of simulation runs can be presented to management directly for decision; the impossible task of ranking and weighing criteria can be taken away from the staff and placed in the hands of the decision maker where it belongs. The great number and variety of simulation studies now in use and being developed are the best evidence of the worth of simulation.



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3. There is no lack of general and expository writing on computer simulation; there is a lack of detail on specific computer programs, flow diagrams, and "hints and kinks."

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A SELECTED LIST OF REFERENCES IN COMPUTER SIMULATION

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ELECTRONIC DATA PROCESSING

by JOSEPH D. HOSIE
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He joined IBM in 1937. His assignments there include: Machine Accounting Dept., Methods Analyst, Registrar - General Education Dept.

ELECTRONIC DATA PROCESSING

By JOHN D. HOSIE

Customer Executive Program, IBM Corporation

Starting the Problem
- Flow Chart Technique
  - Source Documents
  - Cards
  - Files
  - Reports
  - Controls

Selecting a System
- Volume
- Complexity
- Time Deadlines
- Business Expansion
- System Expansion
- Dollar Potential

Types of Systems
- Unit Record
- Magnetic Tape
- RAMAC
- Combinations

Unit Record Approach
- Sequential Processing
- Flexibility
- Timing Considerations
- Modest Cost
  - AM Session — Payroll, Labor Distribution Cost Example
  - PM Session — Billing, Accounts Receivable, Inventory and Sales Anality

Magnetic Tape Approach
- Sequential Processing
- Speed
- Compactness
- Portability
- Variable Record Length
- Storage
- Cost
  - AM Session — Payroll, Labor Distribution, Cost Example
  - PM Session — Billing, Accounts Receivable, Inventory and Sales Analysis Example

RAMAC Approach
- In-Line Processing
  - Immediate Transaction Entry
  - Immediate Updating of ALL affected records
  - Immediate Machine Decisions
  - Immediate Document Writing
  - Immediate Access to Updated Records
  - Compatability with other systems
  - Timing Considerations
  - Cost
    - AM Session — Payroll, Labor Distribution, Cost Example
    - PM Session — Billing, Accounts Receivable, Inventory and Sales Analysis Example

SUMMARY

Analyze *current* and future needs
Study *Basic DP* Approaches
Select Approach that yields the required reports, documents, and analyses, in readily usable form, at the optimum time, to provide maximum savings for the least cift

SIMPLIFIED SYSTEMATIC LAYOUT PLANNING

by JOHN D. WHEELER
Consulting Associate and Principal
RICHARD MUTHER & ASSOCIATES
INDUSTRIAL MANAGEMENT CONSULTANTS

Mr. Wheeler is a recognized authority on planning industrial, office, warehouse, and service-area layouts. He has had extensive management consulting experience in various types of industry on projects involving layout planning, handling analyses, inventory and production control systems, and general management and industrial engineering. He is a co-developer of Systematic Layout Planning. His procedures in arranging engineering offices, training centers, tool rooms, and storage areas have been acclaimed for their practicality and time-saving features.

Mr. Wheeler has been associated previously with the Pennsylvania Railroad, Pacific Jewelry Manufacturing Company, and the Trojan Powder Company. Formerly an Administrative Systems Officer with the Strategic Air Command and Chief Instructor at the Air Force's Radar School in Japan, Mr. Wheeler is a staff lecturer at the annual week-long Midwest Work Courses on Plant Layout and Facilities Planning, and Material Handling Analysis. He is a Cum Laude graduate in Industrial Management and a member of two honorary fraternities. His professional affiliations include the American Institute of Industrial Engineers, Society for Advancement of Management, Institute of Management Sciences, and Industrial Management Society—and he has contributed generously his ideas and developments in talks to numerous technical societies.

SIMPLIFIED SYSTEMATIC LAYOUT PLANNING

A Short-cut Pattern for Small Layout Projects

By JOHN D. WHEELER

Principal, Richard Muther & Associates

ONE OF the more vexing problems of the Industrial Engineer engaged in plant layout activities is that of deciding how much formal investigation and analysis is appropriate for a specific layout project. This is particularly true when the project is small, perhaps involving no more than the rearrangement of a few hundred square feet of floor space, or the relocation and relayout of a service area.

Most of us have handled our layout projects in many different ways, and logically so, for layout projects come in an almost endless variety of sizes and complexities. But it is not so logical that we should permit ourselves to apply either a complex procedure to a simple problem--or a simple procedure to a complex problem.

Many of you are familiar with an approach to plant layout projects that has come to be known as Systematic Layout Planning. Systematic Layout Planning (SLP) is a universal approach for attacking any problem involving the arrangement or layout of space and facilities. It consists of a framework of phases, a pattern of procedures, and a set of conventions.*

For the past several years we have felt that there was a need for a less comprehensive approach, or pattern of attack, that would be suitable to the small layout projects that we encounter so frequently in our work, often as semi-isolated parts of a larger project. As a result of concerted study, specific project experimentation, and further analysis, our staff has developed what we call "Simplified Systematic Layout Planning" (SSLP) to fit this specific need.

*For full description of SLP, refer to the book *Systematic Layout Planning*, by R. Muther (Boston, Industrial Education Institute, 1961)

WHAT S. S. L. P. IS --- HOW IT IS USED

In Exhibit I we have outlined the six-step pattern of procedures that are followed in S. S. L. P., and then have expanded that outline into a complete set of instructions on how to apply the S. S. L. P. pattern to specific layout problems.

The upper portion of the last page (page 4) of Exhibit I shows a diagram of the six-step pattern of S. S. L. P. in meaningful symbols. It also explains the meanings of each of the symbols. The balance of this last page contains a brief explanation of Systematic Layout Planning (SLP) and shows how S. S. L. P. and S. L. P. relate to each other.

S. S. L. P. --- AN EXAMPLE

In order to increase our understanding of this pattern of procedures, let us look at an actual example. This example was taken from a layout project undertaken to plan an expansion in a small vending operation. This vending company is a small independent operation, but it could have easily been a captive operation in support of a multi-building industrial organization.

Exhibit 2 shows this example in detail. Each step is shown in the sequence in which it was performed, and the actual forms used in Steps 1, 2, and 5 are identified. The steps shown follow those outlined in Exhibit I, and were accomplished in accordance with the detailed instructions that are also contained in Exhibit I.

CONCLUSION

This presentation describes the pattern known as Simplified Systematic Layout Planning. It sets forth both a pattern of procedures

and a logical approach to solving layout problems that do not require extensive and detailed analyses of a complex nature.

This approach, and these procedures are a simple device that will help us organize our layout work--particularly when dealing with service areas, offices, or small, low-volume production units.

We can now fit the approach and the techniques to the problem, using the full S. L. P. sequence when needed but saving ourselves time and effort by using Simplified Systematic Layout Planning where it applies.

Instructions for Applying

S I M P L I F I E D SYSTEMATIC LAYOUT PLANNING

Simplified SLP* consists of a six-step pattern of procedures. This includes the following symbolically diagramed steps:

1 Chart the relationship of the activities involved.

2 Establish the space required for each activity.

3 Diagram the relationship of activities and mark the space for each.

4 Draw the space relationship layout; modify and adjust to best alternative layouts.

5 Evaluate alternative arrangements.

6 Complete the selected layout plan, incorporating individual detailed equipment or features, then make ready for installation.

CHART THE RELATIONSHIPS

Relate each activity, area, function, or major building feature occupying floor space to every other activity by a closeness-desired rating.

a. Identify the activities involved.

b. List them on the Relationship Chart.

c. Mark the closeness of each activity to each other activity using the vowel-letter closeness value (A, E, I, O, U, X).

ESTABLISH SPACE REQUIREMENTS

Establish for each activity the required area, physical features, and configuration restrictions.

a. List the same activities, similarly identified and in similar order, on the Activities Area and Features Sheet.

b. Indicate the area required for each activity.

c. Mark appropriately the physical features and any configuration requirements of each activity's space.

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* For full description of SLP, refer to the book Systematic Layout Planning, by R. Muther (Boston, Industrial Education Institute, 1961)

DIAGRAM ACTIVITY RELATIONSHIPS AND MARK EACH ACTIVITY'S SPACE

Relate the various activities to each other visually and in geographic arrangement.

a. Diagram on a sheet of paper each pair of activities having an A-rated relationship--designating each activity and connecting each pair by four parallel lines.

b. Redraw for best arrangement of A-rated activities if needed; then add the E-rated relationships (and any new activities involved)--connecting them by three parallel lines.

c. Rearrange, and add I-rated relationships--connecting by two lines.

d. Rearrange, and add O-rated relationships (connecting by one line) and X-rated relationships (connected by a wiggly line).

e. Rearrange final activity relationship diagram.

f. Mark on the diagram, beside each activity's designation, its required floor space (as established in Step 2).

DRAW THE SPACE RELATIONSHIP LAYOUT; MODIFY AND ADJUST TO THE BEST ALTERNATIVE LAYOUTS

Arrange space required for each activity visually and geographically, and make adjustments and rearrangements to properly integrate all modifying considerations.

a. Establish a suitable scale on cross-section, grid-sheet paper so the total area can be drawn on one sheet.

b. Draw on the cross-section paper the space required for each activity, following the relationships diagramed in Step 3.

c. Adjust and rearrange the layout as appropriate (preferably on similar sheets) integrating the space of the various activities according to their modifying considerations and physical features.

EVALUATE ALTERNATIVE ARRANGEMENTS

Evaluate the various alternative arrangements and select the most suitable for the company.

a. Draw or sketch all space arrangements that seem to be likely solutions--usually two to four layouts. Label each arrangement by letter.

b. Establish all factors, considerations, or objectives the company wants the facility and its space to achieve; list these on an Evaluating Alternatives form.

c. Select the most important factor and assign to it a weight of ten. Weigh the importance to the facilities of each other factor relative to the most important (ten) and indicate its weight on the form.

d. Rate, for each factor, the effectiveness of each alternative arrangement in achieving that factor's objective (A, E, I, O, U, X).

e. After rating each alternative on all factors, convert to numbers (4, 3, 2, 1, 0, -1) and multiply by the weight value.

f. Add the weighted rate values for each alternative arrangement, compare, and select the one most suitable for the company.

---

6 COMPLETE THE SELECTED LAYOUT PLAN WITH DETAILS, THEN MAKE READY FOR INSTALLATION

Draw up the selected layout plan and mark in a meaningful way the individual detailed equipment or features so it can be used to guide the installation.

a. Redraw (or retrace) the selected layout plan, probably at a scale of 1/4 or 1/8 inch equals one foot.

b. Identify the areas and major features, major equipment, and primary installation services.

c. Draw in the detail equipment, machinery, other individual features and utilities or auxiliary services as appropriate.

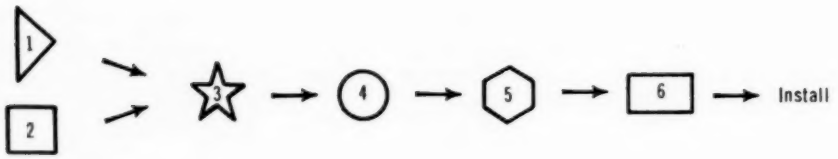
d. Reappraise the fit of details and make minor adjustments as necessary.

e. Show the scale, North direction, the name of the company and the project, the date, and the person drawing the plan.

f. Duplicate necessary copies and prepare to install the plan.

Note: Where an existing building is to be used, the step-four arranging of space can be done by placing a cross-section sheet of tracing paper directly over the building plans or a scaled sketch of the existing floor plan, and diagraming the space on the overlay tracing paper. This is not recommended until at least one space relationship layout has been made independently of existing building considerations.

Simplified S L P Pattern and Symbol Explanation



1. Triangle--relationship chart.
2. Square--square feet and physical features.
3. Star--diagram by connecting activities at different points.
4. Circle--round and round, to modify and adjust the layout.
5. Hexagon--examine from all sides; evaluate all factors.
6. Rectangle--the layout plan on sheet of paper or print.

Systematic Layout Planning (SLP) is a universal approach for attacking any project involving the arrangement or layout of space and facilities. It consists of a framework of phases, a pattern of procedures, and a set of conventions.

The framework includes four phases:

I. Location of Area to be Arranged.
II. General Overall Layout.
III. Detailed Layout Plans.
IV. Installation--planning, move, follow-up.

The pattern includes ten steps or procedures, within each of which there are several techniques which can be used or applied.

The set of conventions includes a combination of coded colors, vowel-letter ratings, numerical values, and symbol designations.

S i m p l i f i e d SLP:

a. Concerns itself with only two of the four phases (Phase II and Phase III, the strictly planning phases of facilities arrangement).

b. It short-cuts the regular SLP pattern (reducing the pattern from ten to six steps).

c. It combines the patterns of Phases II and III.

d. It simplifies the conventions (including only the vowel-letter rating and respective numerical values).

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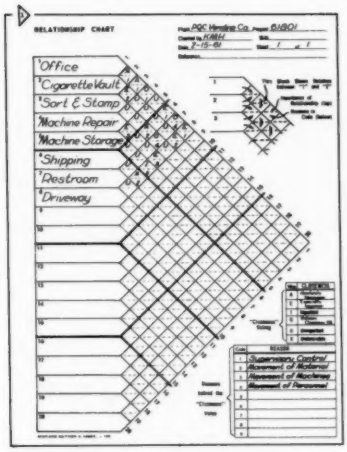
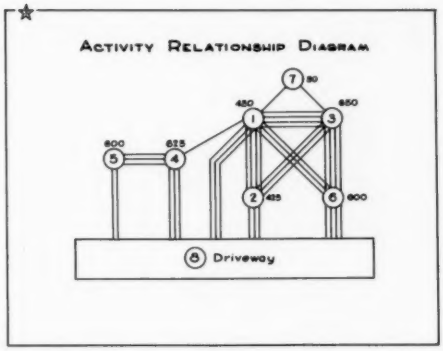
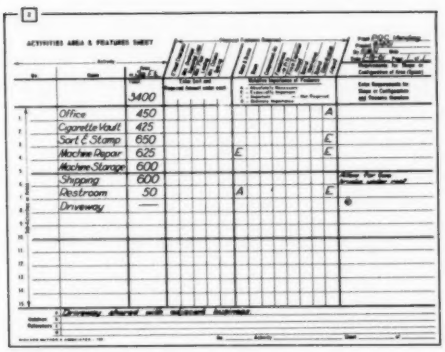
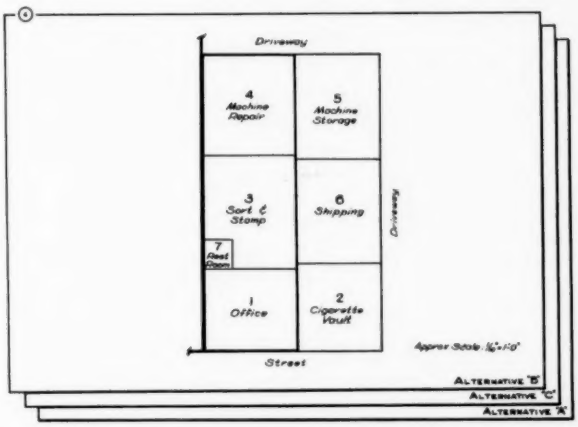
Exhibit II

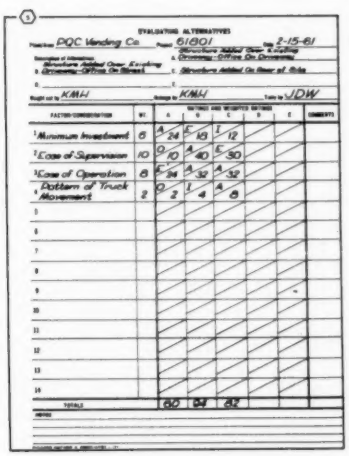


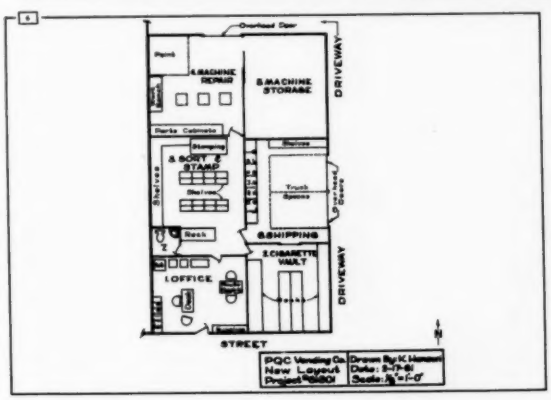
SIMPLIFIED
SYSTEMATIC LAYOUT PLANNING — AN EXAMPLE








EVALUATING ALTERNATIVES
PQC Vending Co. 61801 2-15-61
FACTOR CONSIDERATION
1 Minimum Investment 6
2 Ease of Supervision 10
3 Ease of Operation 8
4 Pattern of Truck Movement 2
TOTALS 80 84 82



Richard Muther & Associates - 2102

NEW ADVANCES IN TIME STUDY ELECTRONIC DATA PROCESSING METHODS

by JOSEPH MOTYCKA, M.E.
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Education: M.E. Cornell University, 1923.

Business Affiliation: Chief-Industrial Engineering—Pratt & Whitney Division, United Aircraft Corporation, since 1940. Developed Standard Time Data and compiled manuals for: Machine Tools, Inspection Operations, Tool Die Making, Cutter Grinding, Machine Repair, and Experimental Machining. Was the first to apply electronic data processing to the task of setting time standards. Co-author, "Electronic Data Processing Comes to Time Study." A.I.I.E. Journal, Feb., 1957.

NEW ADVANCES IN TIME STUDY - ELECTRONIC DATA PROCESSING

By JOSEPH MOTYCKA

Chief-Industrial Engineering, Pratt & Whitney Aircraft Division, United Aircraft Corporation

PERHAPS a more appropriate title for this talk would be, INDUSTRIAL ENGINEERING APPLIED TO INDUSTRIAL ENGINEERING. The modern industrial engineer has been quick and eager to adopt the data processing machine as a new tool for resolving many of his own problems and, also, to put it to use for providing management information within a matter of hours rather than weeks. The data processing machine, therefore, effected a major breakthrough in the management field by providing, quickly and economically, the tools to replace ingenuity with sound decisions based on fact. I believe that Henry L. Gantt once said, "If we allow ourselves to be governed by opinion where it is possible to obtain facts, we shall soon lose in competition with those who base their actions on facts." It should not be assumed, however, that any information generated by the machine is a fact. Its output is no better than its input. Therefore, before delving directly into the adaptation of the computing machine to a particular problem, it might be well to discuss further the industrial engineer's responsibility to examine the validity of the input.

FACTS AND TIME STANDARDS

Fortified with a tape of information, the computer can be instructed to generate, (1) all information necessary to develop a complete manufacturing plan and (2) an integrated system to provide information necessary to carry out the functions of purchasing, planning, dispatching, storing, shipping, billing, and accounting. Thus it can be extremely helpful in carrying out the two important functions of predict and control. Note that (1) is a prediction and (2) is concerned mainly with day to day operations or the function of control. Both systems need facts but the facts in each case may differ. It may be a fact that, during the last run, a certain amount of time was charged to a particular operation. It may be a fact that there is a serious bottleneck developing at a certain work center. It may be a fact that a particular vendor failed to deliver an important detail on time. There are many other facts which are made known quickly by data collecting and recording systems and they become valuable tools for the day to day testing of predictions.

However, to develop a complete manufacturing plan in advance requires a different breed of facts. A well developed plan should be designed to efficiently integrate men, plant, and equipment to produce a definite product mix at a planned rate of production. To achieve that end, the effluence of the computer will affect such decisions as:

1 - How much to make and how much to buy.
2 - The number of employees needed by skills and by work group, including the indirect and supporting functions.
3 - The number of machine tools needed by specific machine type and location
4 - The predicted spares requirements and their effect on the shop load.
5 - The allowable work-in-process inventory based on lead times and economic lot sizes.

The above have been brought out to show the importance of time standards in decision making. Practically all of the above decisions have been influenced by material derived from basic time study data.

THE INDUSTRIAL ENGINEER AND TIME STUDY

It is recognized that the modern industrial engineer wants little to do with time study. He would rather delve into the more glamorous phases of the science. He prefers the more highly specialized techniques of linear programming, queueing theory, simulation, multiple regression, and various other statistical analyses for solving some of the more complex problems of management. However, when he is handing out information which relies heavily on time study data he should concern himself with its validity. If he is a true industrial engineer he will also examine the tools and methods of production of time standards within his own bailiwick. Perhaps he can apply statistics to test the validity of the basic data. Perhaps he can time study the job of setting standards. Perhaps he can utilize the computer to further improve production within his own department.

THE STATISTICAL APPROACH TO STANDARD DATA

Of the tools mentioned, the most important is a catalog of standard elements with their assigned time values. It is recognized that there are many systems in vogue for the determination of elemental time values but, herein, the statistical approach will be the only one discussed. Statistical theory states that, given a normal population of workmen each performing the same task in the same manner, the individual time readings, when plotted, will form the statistically normal or Gaussian curve. That theory has been proven and, therefore, is regarded as law within the scope of this dissertation.

To compile a catalog of standard data, it is not recommended that old data, extracted from the files be used. The recommended staff would consist of an industrial engineer, stopwatch men, clerks, experts in the art of metal cutting, and above all a statistician. The statistician's responsibility would be to test the raw data. If it conforms for a particular element, the mean value can be readily accepted and no further study of that element is necessary. He will find that, in all cases where the data did not conform, the population was not normal, the stop-watch men did not have a uniform conception of the element, or there was a hidden variable. Thus, the statistician becomes the chief inspector. Like all inspectors he should have a tolerance. For example, it can be expected that 99% or more of the individual stop-watch readings depart less than three standard deviations from the mean and that the probable variation of the mean values for an unlimited number of samples is 10% or less of the selected figure 95 times out of 100.

The number of basic elements to study depends, of course, on the nature of the business. However, it has been found that a number of around 300 is sufficient to form an almost unlimited number of combinations to handle any operation in a complex machine shop. Of course, each element may vary within itself therefore the number of time values will greatly exceed that number.

LINE PRODUCTION OF TIME STANDARDS

With the catalog of standard data available as a tool, the next step is to determine a reasonably efficient manner of application. Usually, by the time the catalog is ready, there is a tremendous backlog of time study work and a short supply of qualified analysts. The logical step, in such a situation, is to study the job of the time study analyst with a view toward a separation of skills. Such a study would reveal that there are four separate skills involved each of which can become a specialized operation as follows:

1 - Determine the correct manner of performing the task.
2 - Assign the necessary elements and their respective time values.
3 - Calculate the time standard.
4 - Write a task card, key punch an IBM card, perform incidental clerical tasks, and file.

Operation 1 requires a recognized expert in the operation of each of the basic types of machine tools used. For example, the lathe expert should be an authority on the setup and operation of turret lathes. He should be able to analyze the cuts specified and to recommend the setup and tooling.

Operation 2 requires a time study analyst.

His job is to analyze the method prescribed in Operation 1, assign the necessary basic elements, check the cutting speeds and feeds, and assign the applicable catalog values.

Operation 3 requires a comptometer or similar computing machine operator.

Operation 4 is self explanatory. The key punch operation is necessary inasmuch as it is assumed the standards are to be used for the analyses cited previously.

Thus it can be seen that the task of setting time standards can be divided and operated on a line production basis.

Although the line production method of performing time study work is a step forward and can increase the production of time standards threefold, further study may reveal still further improvement.

THE NEXT STEP - DATA PROCESSING

With the advent of computing machines the next step becomes obvious. It can be reasoned that, since the machine has a so-called memory unit, it should be able to memorize the entire contents of the standard data catalog. If it can be instructed to refer to the catalog and pick any value stored therein, it can eliminate the necessity for manual "look-up". If it can calculate, which of course it can, it will obviate manual calculations of the time standard. If it can print, it can write the task card.

The following is a brief description of the manner in which the IBM 702 EDPM is being applied to the task of setting time standards.

The catalog of standard data was transformed into a magnetic tape and, therefore, no longer was the important tool of the time study analyst. The machine was instructed to perform all calculations thus idling the beloved slide rule.

The new tool is now called a document. Computers have brought forth a new language and the word "Document" in their sense, means original instrument for conveying input data to the machine. A document must be designed to facilitate key punching and it must conform to the particular program for which it is intended. The program, in computer language, is the detailed operation instructions for the machine to follow. Figure 1 shows a document for computing a time standard for a typical turret lathe operation.

In order to assist the time study analyst in the document, there is a prepared handbook of instructions. However, once these instructions have been memorized, the procedures become routine and reference to the handbook becomes unnecessary.

It will be noted that this particular document contains practically all elements incidental to the operation of a turret lathe. The variables within those elements are stored in the machine either in tabular form or as mathematical equations. The top section is called the Heading Card. Important here is an accurate coding of the type of machine, material and its hardness, weight of the part, and the department where the work is to be performed. Those items will tell the computer to get ready to seek out the correct value of each variable, depending on its respective time value. For example, it will know that this operation is to be done on a #4 W&S Turret Lathe whose gears will produce a limited combination of speeds and feeds. It will also know that there is a table available from which to select the standard cutting speed for the specified material. Knowing the diameter of the cut and the standard cutting speed it will calculate the necessary R.P.M. It will then refer to the combinations available on a #4 W&S and select the speed most appropriate, within instructed limits, and then go on to calculate the cutting time. Incidentally, it will also add pre-travel and over-travel if asked to do so.

The standard coded elements are relatively simple to apply and need only checks or numbers written in the proper spaces. For example, the element CLEAN CHUCK needs only a check to show it will be performed, and a figure one to show it will be done once per piece. The same holds true with the element LOAD CHUCK. For the element GAGE, DOUBLE ENDED CYL. PLUG a check shows it is necessary. A (1) shows it is to be done in one position, and another (1) shows it happens on 100% of the parts. It is inserted one inch and its diameter is approximately .6 inches.

Figure 2 shows a STANDARD TASK CARD. It is made available to the shop to show the method recommended and by which the standard was established, and other pertinent data. The printing of the STANDARD TASK CARD is also part of the computing machine's duty.

TIME STUDY DOCUMENT–LATHE STANDARD

FOR USE WITH I.B.M. 702 ELECTRONIC DATA PROCESSING MACHINE

PART NUMBER	OPER. NO.	CARD NO.	DEPT. NO.	PART NAME	TYPE OF MACHINE	MACHINE CODE	LATHE CODE	MATERIAL	H	WGT	PCS./PER LOAD	M/C	DATE: 5-6-57
15391	0003	1	0012	SHAFT GEAR W+S	NO 4	20030	5	A6260A	02	001	1		ANALYST: MEISCH

STANDARD CODED ELEMENTS

STANDARD GAGES	Check	Code	Basic Checks	Plan	Add. Chks	Variables
SNAP - D.E. Length	✓	001	01	1000	001	
Progressive Groove		002				
Std. Progressive	✓	003	01	1000	002	
INDICATOR - Dial Bore		004			0	
Federal Snap		005			00	
Flush Pin		006				
Calipers		007			00	
Flatness Check		008			DPH DIAM.	
PLUG - D.E. cyl. under 001		009				
D.E. cyl. over 001	✓	010	01	1001	006	
Progressive Cyl.		011			.25	
Progressive Flat		012				
D.E. Flat		013				
MICROMETER - O.D.		014			0	
Depth		015			00	
I.D.		016			00	
MISCELLANEOUS - Radius	✓	017	01	010		
Chamfer	✓	018	01	020		

STANDARD CODED ELEMENTS	Check	Code	Basic Checks	Plan	Add. Chks	Variables
Straight Edge		019				
Calipers O.D.		020			0	
Flush Pin	✓	021	01	1000	005	
Profile Template		022				
Width Gage		023				
HANDLING ELEMENTS						
PICK & ASIDE PART	✓	024	01	0		
CLEAN CHUCK	✓	025	01	0		
CLEAN PART	✓	026	01	0		
CLEAN CHIPS - Short	✓	027	04	0		
Long		028				
STEADY REST		029				
LOOSE BUSHING		030				
SPRING BUSHING		031				
SLIDING CLAMP		032				
PICK & ASIDE WRENCH		033				
LOAD CHUCKS - Air		034				
Spring		035				
Extension Bar		036				

STANDARD CODED ELEMENTS	Check	Code	Basic Checks	Plan	Add. Chks	Variables
Manual	✓	037	01	0		
Move Jaws		038				
BREAK SHARP EDGES		039				
SET TO INDICATOR		040				
SPLASH GUARD	✓	041	01	0		
TGT. & LOOSEN NUT-Hand		042			00	
-Wrench		043			00	
Flush Pin	✓	021	01	1000	005	

TIME STUDIES & ESTIMATES	Check	Code	Basic Checks	Plan	Add. Chks	Variables	Minutes
Tag Work	✓	100	01	1000	009		

Control	Description of Operation	Tool	Length of Cut	Depth of Cut	Feed	Change Speed	Feed	Adjust	Adv. & Back Hex	Back Index & Adv. Hex	Index Square Turret	Move-Hand	Move-Rapid	No. of Inches
	Finish / Operation / Location / Dimension	Number / Material / Radius	Net / Pre- or Over-Travel	Dimension Before / Dimension After	Per Revolution	Start & Stop Spindle / Position to Cut.-Cr.-Slide / Lock & Aside & Unlock / Position Aside Size Bl. / Position Coolant Aside / Pre-Selector / Per Lever / Button / Change Per Lever	Reverse / Engage / Stop Roll / Stop Rod / Over 002 / Under 002	Dial & Lock / Small Ram / Medium Ram	Small Ram / Medium Ram / Pilot Bar	#1 / #2	Cross Slide / Carriage / Cr. Sl. Carriage	Cross Slide / Diag. Cr. Slide / Hex Carriage	Hand Feed	
y	R 02 01 .3727	1C 06	1275	0502 0402	065	1 1 1 1 1	1 1	1	1		88			
	R 02 02 1.9421	1C 06	0625	2062 1.9370	32	1 1	1				24			H
	R 01 03 1.0062	C 06	1940	1.2501 1.0600	75	1 1	1 1	1	1	1	88			
	F 01 03 1.0063	C 06	1940	1.0501 1.0060	75	1 1	1 1	1	1	1	88			
	1014													
	E 02 01 .3723	C 06	1397	0402 0377	065	1 1	1	1			22			
	1013													
	F 02 02 1.9424	C 03	0500	1962 1.9420	65	1 1	1	1	1	1	88			
	0704	4C	0058			1	1	1			22			H
	15	AH	0600		030		1 1		1		66			H
	04	.5318H	2415	0600 0000 0531	045	1	1 1 1	1	1					
	03	.5447C	C 03	0787 0600 0531	045	1	1	1	1					
	0915	AH	0006	0002		1	1 1 1 1	1						H

Fig. 1

STANDARD TASK CARD

DATE 5 13 57 TYPE MACHINE W & S NO. 4

DEPT. NO. 121 PART NO. 153919 OPER. NO. 3

MACHINE OR BENCH OPERATION		TOOL	LENGTH OF CUT	FEET P/MIN.	R.P.M.	FEED		TIME
ROU FACE SH	.377	1	1.275	420	423	0065		.46
ROU FACE END	1.942	1	.625	276	846	HAND		.23
ROU TURN SHANK	1.006	2	1.940	276	846	0075		.31
FIN TURN SHANK	1.006	3	1.940	230	846	0075		.31
BLEND TO STOP								.08
FIN FACE SH	.377	3	1.397	420	423	0065		.51
BLEND TO CLIP								.08
FIN FACE END	1.942	4	.500	230	846	0065		.09
CHAMFER O.D.		4	.058	230	846	HAND		.10
CENTER		A	.600	130	846	HAND		.24
DRILL	.531	B	2.475	49	354	0045		1.55
BORE	.544	C	.847	120	846	0045		.22
PEEL CENTER		A	.007	6	30	HAND		.23

ALLOWED
PIECES PER HR. PER MACHINE
5.5
TIME PER PIECE
10.97

SUMMARY
PER LOAD
EXT. HAND TIME
5.56
EXT. MACH. TIME
4.41
INTERFER. ALLOW.
-
TOTAL
9.97
PER PIECE
TOTAL MACH. STD.
9.97
TOTAL LABOR STD.
9.97

PERTINENT INFORMATION PCS. PER LOAD 1 MACHINES PER OPER. 1 HELPER'S TIME PER LOAD

ALLOWED TIME & PCS. INCLUDES 10% FOR PERSONAL & SHOP PRACTICE ALLOWANCE

Fig. 2

It receives instructions from the machining section of the Document by means of a system of codes. For example, under DESCRIPTION OF OPERATION, column 18 of the document, the letter R means ROUGH, the 02 in columns 19 and 20 means FACE, and the 01 in columns 21 and 22 means SHOULDER. Thus, the machine will print, for the first cut, ROUGH FACE THE SHOULDER in abbreviated form. Columns 23 through 26 identify the cut by its dimension. Column 27 shows the tool number (1) and the (C) in 28 specifies a carbide tool. The next four columns show the net tool travel. If there is any pre or over-travel to be added, it will be done automatically. Note that 38 through 45 show the dimensions before and after the cut, the difference being the depth of cut, which is also automatically calculated. On radial cuts the computer will automatically use half the difference to get the depth of cut. The feed per revolution is specified by the analyst who will also fill in the spaces showing the occurrences of each element incidental to each cut.

Note - On the last cut PEEL CENTER there is an allowance of .002 inches for overtravel. The reason is to allow a few revolutions of so-called "Dwell" to assure a smooth finish.

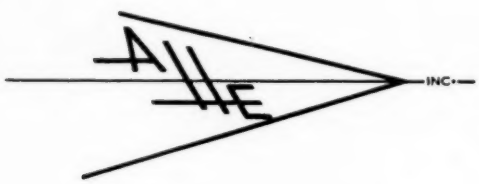
Thus it can be seen that in a rather uncanny way, the EDPM-702 can open the Standard Data Catalog to the right page, run a finger down a column of numbers, across to the correct figure, store it and then select another value from another page, carry it to the first number and perform any necessary combination of additions, subtractions, multiplications or divisions. It can also print the result, but may first refer to another table to check whether or not the resultant number is practicable and if not, print one that is. It can do all of the above provided, of course, that it has received the proper instructions and that the proper squares are properly marked.

CONCLUSION

Aside from the time saving element, there

are other hidden factors which enter into the picture. Whether they are advantageous or not is, of course, debatable depending on the character of a particular organization but, nevertheless, in the interest of standardization, they are felt important. For example, the use of a relatively few standard elements to establish thousands of time standards tends to bring time study closer to an exact science and the use of specialists in certain types of operations tends to unify the thinking. The cutting speeds become standardized, and fewer types of cutting tools, grinding wheels, etc. will be specified. It can be stated that if a few standards are loose all of the standards are loose, and if a few are tight all of the standards are tight and by the same proportion. Variations in operating costs can be measured and their reasons investigated with a minimum of investigation.

It is considered entirely feasible to apply uniform standard data throughout the metal trades, using the electronic data processing machine as described herein. There would be differences in performance, to be sure, but investigations may disclose such factors as poor cutter grinding, a lack of machine tool maintenance or differences in shop tempo.



CONTROL OF OVERHEAD COST THROUGH AN INTEGRATED MANAGEMENT INFORMATION SYSTEM

by DR. ROBERT G. STEVENS, CPA
Acting Director - Financial Management
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Experience: Presently - Acting director - Financial Management, a research and development activity of the Management Services Central Staff of Touche, Ross, Bailey & Smart, Certified Public Accountants. His work is primarily concerned with the design and development of systems for the control of performance and the provision of information relevant to planning and decision-making. He was formerly a member of the audit staff. His experiences in public accounting have taken him into advertising, agriculture, banking, construction, manufacturing, merchandising, and public utilities.

Instructor of accountancy at the University of Illinois for four years.

Military training officer in the Flying Training Air Force.

Cost accountant for the Military Air Transport Service.

Education: Ph. D. and M. S. degrees from University of Illinois.

Bachelors degree from Southern Illinois University.

Graduate of USAF Officer Candidate School, attended George Washington University, Texas Technological College, and the Economics-in-Action Program at the Case Institute of Technology.

General: CPA in State of Illinois.

Member of Phi Kappa Phi and Beta Alpha Psi - honorary academic societies. Member of the Masonic Lodge in Marion, Illinois. Member of American Accounting Association.

Author of *Economic Theory and Accounting Principles*, "A Motivation Program to Increase the Effectiveness of Accounting Courses," and "How 'All Purpose' Data can Defeat Good Management."

CONTROL OF OVERHEAD COST THROUGH AN INTEGRATED MANAGEMENT INFORMATION SYSTEM

By ROBERT G. STEVENS, Ph.D., C.P.A.

Acting Director - Financial Management, Touche, Ross, Bailey & Smart

THE CONTROL of overhead cost is a how-to-do-it-kind of subject. This is often interpreted to mean that the discussion of the subject should concentrate on minute details. In a cost control system, however, the minute details are difficult and even impossible to understand out of the context of the objectives and characteristics of the system of which they are a part. This is true because cost control systems and all accounting systems, for that matter, are systems of logic. Logic requires us to define objectives and basic premises. Without orientation to these bases, we deal with a disorganized structure in which all answers can be right because they stem from different assumptions, and disagreements cannot be resolved until the arguments begin to revolve around these assumptions. The first effort in this discussion, therefore, will be directed at objectives and basic assumptions of a cost control system. A review will also be made of cost characteristics and the relationship of cost control to organization structure. Once the conceptual framework is established, procedures will be illustrated which implement the concepts that have been developed.

A REVIEW OF COST CONTROL FUNDAMENTALS

A cost control system is intended to provide management with information and procedures which will enable management to effectively regulate, direct, discipline, and influence costs. The means by which this objective can be achieved are greatly influenced by the nature of cost itself.

Cost is a many-sided concept. In one sense, cost is synonomous with cash outlay or expenditures. In another sense, cost represents the value of goods or services consumed, exchanged, or otherwise used up. In this latter concept, the word value can have several different meanings. It may mean goods and services valued at their original cash outlay; it may refer to present market value or to value under some special set of circumstances. This aspect of cost is of primary significance in the valuation of resources and in income determination, but it is important at only one time in cost control, and that is at the time of the purchase of a good or service. It is at this point that we must be sure that the price we agree to pay is the best available for the good or service desired. The concepts of value involved are clear. We are concerned with the present values of the cash outlays required to obtain the goods or services from the alternative sources, and we must have some concept of the value which can be generated through the utilization of these goods or services.

The purchase price decision is very often the crucial one for raw materials, goods for resale, and for labor. Control of price may be less significant for overhead expenditures. This, however, should not be an automatic assumption. The determination of the crucial problem areas should be fundamental to the development of the control system.

In addition to being a concept of value, cost is a concept of the consumption or utilization of products and services. At the operating level, this is an important distinction. Distinction, in fact, may be the wrong word because the operating man may not be aware at all of the valuation side of cost. He sees only man hours, tons of steel, gallons of cutting oil, hours of machine time, feet of weld, wrenches, paper, and all of the other real things that are consumed or utilized in the process of production. Efforts to educate operating men to the fact that time means money, and so on, are

worthwhile. This may even be an objective of a cost control system, but the fundamental thing that must be understood is that it is the hours, tons, and gallons that must be controlled. Dollars are a by-product - a result. Dollars may not provide a meaningful basis for cost control.

In order to exercise any form of control, limitation, or restriction, it is necessary to have some criterion, some goal, or objective. The control of some activities, driving a car, for instance, is reflexive and intuitive; other activities are controlled by taste or by custom and other highly subjective factors. Missiles, on the other hand, are controlled by very specific objectives and by very formal systems. Even in the most informal systems based on the most subjective factors, the objectives must become definitive at the point at which control is to be exercised. The most abstract artist in mixing his paints must become definitive in order to know when the colors have blended to just the shade he desires.

In the case of cost control, there are at least four elements that form the limits, objectives, or standards for cost control. Value is one of these elements, and this has been discussed to some extent. Necessity is an element that is defined in terms of what specific materials, supplies, and services are needed. Perfume is not likely to be an acceptable supply for the machine shop. Quality is an element that forms the physical substance behind value and is also a determining factor in establishing specifications for necessary supplies and services. The fourth element is quantity. Time is either a fifth element or else a further dimension of quantity. In order to exercise control, each one of these elements must be defined. A controlled course of action can be obtained only by knowing what supplies and services are required, what quality is needed, what price should be paid, and how much should be used.

Quantity, in most cases, is the significant element to be controlled. The determination of allowable quantities is not a simple process, and the problems involved are fundamental to control. Quantity, for example, may relate either to a planned activity level or to the actual activity level achieved. These two bases are quite different and are a source of confusion. Let's assume the following facts for a machine shop:

	Planned	Actual
Hours of Activity	200,000	100,000
Reasonable cost for electricity at each level	$300,000	$180,000

Some systems intended for cost control would set up $300,000 as the limitation on the expenditure for electricity. It seems obvious that if only 100,000 hours are worked the cost of electricity should not be $300,000. The machine shop superintendent is not due for congratulations if he spends his entire budget. An engineered standard might tell us that $180,000 is the amount that should be spent if we work at the 100,000 hour level. The difference here is a confusion of controls. Volume or activity goals, such as the 200,000 hours, should be established. They become a part of a control mechanism for carrying out a plan of activity, plant utilization, and sales volume. Their relation to cost control, however, is incidental. A cost control system must measure and compare actual performance at actual levels of activity against allowable or desired performance at those same levels of activity.

The solution to this first quantity problem leads to a second problem - how should the use of goods and services relate to activity? The specific figures needed to answer this question are somewhat difficult to come by, but the general answer is very simple. It can be recognized that the consumption of welding rod is going to be a function of the number of feet welded. Use, in this case, should be proportional to activity. Establishing the number of welding foremen required is more difficult, but it is easily recognized that the need for foremen is not directly proportional to welding activity. In the normal range of activity of many plants, only one welding foreman would be required; and even in ship yards, where welding is a significant operation, the need for additional foremen would occur only at wide increments of activity.

If our control system is intended to give us an index of allowable expenditures, and this is what it should do, then, in establishing allowances for expenditures at various levels of activity, these allowances must reflect the physical patterns of consumption in a given state of technology.

In addition to the elements discussed above, the control problem has another unique and fundamental quality which is often not considered by economists, accountants, or even industrial engineers. No matter how much mechanization or automation there is in industry, the consumption of goods and services is under the control of people. Someone is responsible, and measuring in terms of responsibility must be an integral part of any effective system of control.

This last fundamental might be called the communication fundamental. In all systems, it is necessary to be able to read and compare actual conditions and trends with those desired. Control cannot be exercised unless both actual conditions and desired objectives are clearly defined. This does not mean that these facts must be reduced to writing or generated by formal data processing systems, but it is not very likely that cost control will be achieved without formal systems. The degree of sophistication of the communication system must be a balance between the cost of the system and the value of the service it can render.

BUILDING A SYSTEM TO MEET CONTROL OBJECTIVES

Building a control system is a process of implementing fundamentals. Where to begin depends upon the circumstances, but most programs will begin with some efforts to justify the need. This is a matter of identifying the critical problem areas, obtaining at least some rough trends of how costs may be increasing in relation to output, and some comparison of cost, profit, or return on investment with other companies in the industry. This information should be used to determine the scope of the system and the over-all end result that is desired.

Since these desired results will be meaningful only if they are related to the responsibility structure of the organization, the efforts to define responsibility will be one of the most critical elements in the system. In most cases, these units will become a framework through which the other outputs will be defined, and, therefore, must be developed before standards, measures of activity, budgets, and other tools are developed.

Establishing responsibility is not an easy task. It is particularly difficult to define responsibility in the areas of maintenance, quality control, methods, tools, scheduling, and material handling. For instance, is maintenance in a machine shop a responsibility of the machine shop foreman, the plant manager, the maintenance foreman, or the director of engineering? There are even problems of saying what is the machine shop, what are the boundaries of the grinding shop, what is the difference between fabricating and assembly, and what happens when a foreman is transferred from assembly to fabricating, and how do we define responsibility for shifts within a department. There are some manufacturing plants where plant responsibility will run by function so that one foreman might be responsible for all welding, and welding might be done any place in the plant. A foreman might also be in charge of all government contract work; and in this case, responsibility would follow a product line rather than a functional type of work.

Once the responsibility units have been determined, two kinds of information must be provided for each of the responsibility units. One, we must have a schedule of allowable expenses and, second, we must have a way of measuring actual performance against this allowable expenditure of hours, material, and money. These considerations may affect our definitions of responsibility. It is best to start out with an over-definition of responsibility and then later reduce the number of responsibility units if measuring actual performance against a plan is found not to be feasible because of the amount of effort required or the value of the controls to be gained.

We do not wish to discuss the matter here, but it may also be found that within a responsibility unit there are sub-centers which have markedly different cost characteristics. The machine shop, for instance, may have a turret lathe and also a press brake. Certainly we recognize that the tools, cutting oil, and electricity associated with a turret lathe create overhead costs that are considerably higher than the overhead costs associated with the operation of a press brake. From a responsibility point of view, this distinction may have little value, but we will find later that we must use these responsibility units as building blocks for product cost; and when we are

talking about product cost, there is a significance. One product may go through the low overhead department while another may go through only the high cost sub-center. Unless this is recognized, certainly we will not get a correct statement of product cost.

After responsibility units have been determined, the next step in building a cost control system is to determine schedules of allowable expenses for each of the units. Exhibit I is a simplified example of such a schedule of allowable expenses. This exhibit tells the machine shop foreman that when he is operating

MACHINE SHOP - *FLEXIBLE BUDGET*

LEVEL OF ACTIVITY:					
% of Practical Capacity	40%	60%	80%	100%	120%
Standard Direct Labor Hours (000)	40	60	80	100	120
Standard Direct Labor Cost (000)	$80	$120	$160	$200	$240
OPERATING COSTS: (000)					
Supervision	$31	$31	$39	$39	$47
Material Handling	25	43	48	50	65
Maintenance	16	21	28	35	44
Clerical	6	6	6	6	6
Supplies	32	48	64	80	96
Utilities	25	34	43	52	61
Other Costs	75	100	110	120	135
TOTAL OPERATING COSTS	$210	$283	$338	$382	$454

Exhibit I

at 40,000 standard direct labor hours his supervisory cost should be $31,000 for the year. Material handling should be $25,000, clerical cost $6,000, utilities $25,000, other costs $75,000, and total operating costs $210,000. It further states that if he operates at 100,000 direct labor hours, for example, he is allowed to spend a total of $382,000. It is significant to note that $382,000 at 100,000 hours is not 2 1/2 times greater than the $210,000 allowed at the 40,000 hour level.

In Exhibit II, the behavior of some of the costs from the flexible budget has been illustrated graphically. It will be noted that $6,000 is allowed for clerical costs regardless of our level of activity. Therefore, this cost behaves as shown in Graph II D. This means, of course, that the way the machine shop is operated requires the same number of clerical persons regardless of activity. Whether or not this is the most efficient procedure for the machine is another question. Unless this organizational setup is challenged and changed, then this state of technology forms the base of the flexible budget.

COST BEHAVIOR

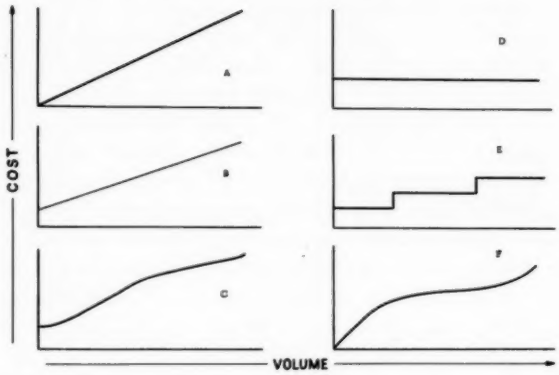


Exhibit II

Supervisory costs behave somewhat like Graph II E. Up to 60,000 direct labor hours, supervisory costs are $31,000. At 80,000 hours, they step up to $39,000, and step up another $8,000 at 120,000 hours. The operation of the equipment in the department requires the consumption of supplies in proportion to activity. If this is true, then supplies for this department are a purely variable cost - Graph II A. The utility cost is fairly well represented by Graph II C. Electricity, for example, is priced on a flat base rate plus a declining rate based upon usage. Graph II F would represent some cost that does not have a stand-by component but moves up at a rather high rate when our consumption of that factor is low; but then evidently we are able to buy that factor cheaper when we use it in higher volume and, finally, if used in very large quantities, the supply, perhaps, becomes limited and the price goes up.

The big question, of course, is how to get the figures in Exhibit I. How do we know that supervision is $31,000? How do we know that supplies at 80,000 direct labor hours would be $64,000? Exhibit III is a sample of the effort that must be made in order to find indirect labor cost. Here we have a production control department, and we are trying to build a manpower budget for various levels of activity. The Manager, Mr. H. R. Walters of the Production Control Department, was asked to submit his proposed Production Control Department budget. The total figures for his first

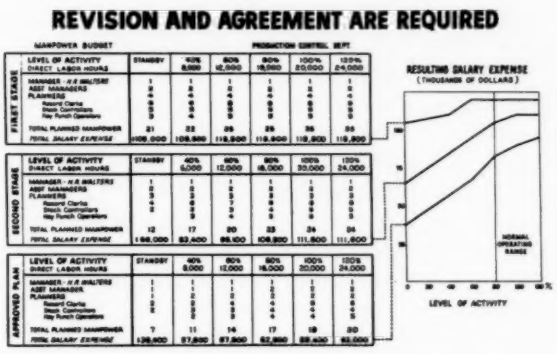


Exhibit III

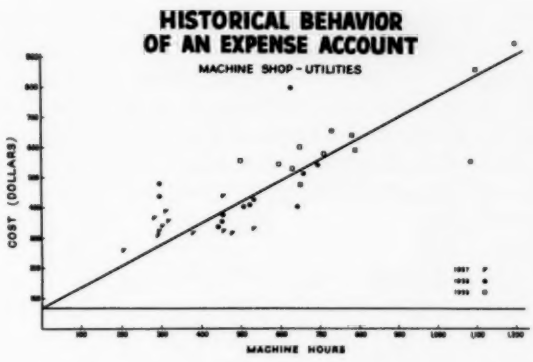


Exhibit IV

draft are represented graphically on the right-hand side of Exhibit III. Note that the level of stand-by costs is very high. There is a sharp increase in the rate between 40 and 60% of capacity. This first draft was presented to the director of manufacturing and reviewed. Evidently, Mr. Walters was asked to reconsider. Notice that in the second stage he considerably reduced the planned stand-by costs. He has also developed a program where he does not add people until activity starts to move upward. Even this second budget is revised, and the final approved plan shows an even greater relation to activity. This then would be a manpower table worked on by the manager of the department. He must agree that he can operate with this table. This gives him a plan of action to work under. With this plan, he is able to determine whether hiring another man is in conformity with his budget. He is also permitted to spend more money when he is operating at a higher level of activity. He is able to have control before the fact - before the horse gets out of the barn.

Exhibit IV is an example of the historical behavior of the machine shop's utility account, and sometimes this type of graphical approach is used to determine the allowable expenditures at different levels of activity. This provides a useful test of the budget, but it is not a very reliable basis for establishing the allowable amounts. The allowable amounts for items such as supplies, utilities, and other non-labor costs should be established in the same manner as the manpower table. This is a place where the basic unit of budgeting may not be dollars but physical units. For instance, the budget would be in terms of kilowatt hours that would have to be used in this department at different levels of activity, the number of cutting tools to be used, the gallons of cutting oil, and other major items of expenditures. The historical approach for minor items is acceptable, but the big ones should be done on a carefully planned basis. Otherwise, we may be using past mistakes as a yardstick.

Past history can also be very confusing because of bookkeeping problems. The cost of an item may be recorded in the month before it is used or the month after it is used and inconsistently from month to month. The treasurer might have been holding up bills, or he might have wanted to get everything paid. The bookkeeping records do not necessarily show expenses on a usage basis. It is very important that when we are comparing allowable expenditures with actual expenditures we are certain that we are measuring both on the same basis. If the budget is built on usage, then our actual should be on usage. If we are measuring on an expenditure basis, we may have to account for leads and lags against our activity basis. This may be very complicated.

The cost control system proposed here has been based upon two primary assumptions. First, it has been assumed that costs can be controlled only by people. Therefore, as a first step in the design of a cost system, we have proposed an analysis of the organization to define responsibility either for cash expenditures or for the physical factors which cause cash expenditures. Second, we have built our cost control system on a concept of cost behavior which recognizes that each cost may have varying degrees of stand-by and variable elements. We have, therefore, built

allowable amounts of expenditures at different levels of activity, and the amounts of allowable expenditures have been determined as objectively as possible. Third, we have assumed that control must come through knowing not only what is allowable but what is actually being spent and perhaps what may be required in the future.

INTEGRATING THE CONTROL SYSTEM WITH OTHER OBJECTIVES

In the beginning of this study, objectives of a control system were contrasted with the objectives of product costing, income determination, asset valuation, profit planning, and evaluating alternative courses of action. Efforts were made to keep these objectives separate and not confuse them. This is still the rule, but at this point, it is time to explore the complementary relationship that each of these objectives and their respective data processing systems have to a cost control system.

The cost control system is very closely related to product costing. Although a control system is built on a responsibility framework, each of the responsibility units may have some contact with making a product. Each product that is manufactured should have a set of specifications which would provide us with the labor and material cost required to make that product. The overhead cost related to the production of a product is derived from the flexible budget for each of the responsibility units which were described above. This is what we mean when we say that responsibility units become building blocks for product costs. The critical question in product costing is simply how much of the overhead cost of each responsibility unit should be charged to a given product.

Unfortunately, there is no such thing as a single value which represents the "true cost" of any product. We must know the true cost for a given purpose. The true cost for income determination is not the same as the true cost for adding or dropping a product. In fact, the true cost of adding is not the same as the true cost of dropping. In other words, the word "true" must be interpreted to mean a cost which is valid in relation to the decision in which it is being used - one that will lead to logical conclusions.

If we are trying to determine how much a given product adds or subtracts from the net profit of the company as a whole, then we need to know the variable costs of that product. We need to know the standard direct labor and the standard materials associated with that product plus the variable overhead costs that are created as a result of the manufacture, distribution, and sales of that product. These overhead costs can be derived from the flexible budget of each of the responsibility units. For example, the overhead cost of the machine shop may be related to direct labor hours. Therefore, if our product is worked on in the machine shop, this product should cause the overhead cost of that department to increase in proportion to the amount of direct labor involved in the production of that product. These overhead costs then are clearly incident to the manufacture of that product.

Now it may seem paradoxical that to measure the effect of a given product on net profit we do not attempt to determine the net profit of that product. Let's think about this for a minute. In Exhibit V, we attempt to define graphically how the effect on net profit is measured. We call this effect "profit contribution." The top figure in Exhibit V is simply the total sales line for one or all products. It simply shows a straight line increase in sales. In the middle figure, we add a line for variable costs. Now this line is also a straight line, and it moves up as more units are sold. These are the variable costs we were talking about above. The difference between sales and variable costs of those sales is profit contribution. This is the effect of sales on net profit. In the bottom figure, we add the stand-by and program costs. These costs are not related to selling one more unit - not related to volume. Without any sales at all, the amount of a loss would be the amount of stand-by and programmed costs. With every increment of sales in which the selling price is in excess of the variable costs, this loss is reduced until finally we reach a break-even point. A break-even point is a point at which profit contribution equals the amount of stand-by and programmed costs. Profit contribution is, therefore, the amount by which a loss is reduced or a profit increased.

If it is our objective to determine the true cost of a product for purposes of inventory

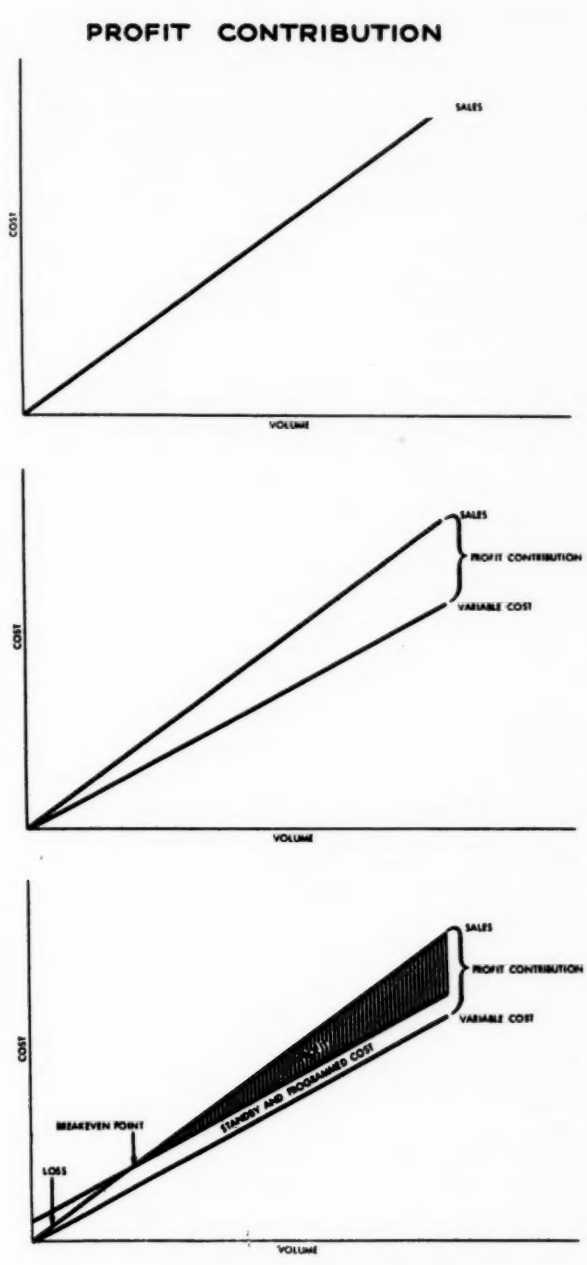


Exhibit V

valuation, then we are dealing with a completely new set of requirements. Inventories are sometimes valued at current selling price minus an anticipated cost of distribution and minus normal profit. The reason we are deducting normal profit here is that generally accepted accounting principles require that we do anticipate any profit prior to actual consummation of a sale. This kind of valuation is actually the acid test of inventory costing. This is another way of stating the auditor's concept of cost or market, whichever is lower. Market value will certainly reflect some portion of the stand-by costs that are necessary to establish a business with the capacity that is necessary to make a product. Therefore, when we are determining costs or attempting to build up the cost of a product for inventory purposes, we want not only the variable cost of the product, but we would also want to charge that product with some equitable portion of this stand-by cost of the business. As it happens, some stand-by costs are actually identifiable with a product line. For instance, the firm may have a salaried salesman that is devoted exclusively to the sale of a given product. It may be that some manufacturing department exists entirely for the purpose of processing some single product. It could be that an entire plant exists for the purpose of producing a single product. In these cases, the stand-by costs of these responsibility units can be clearly identified with a product. Most stand-by costs, however, are not likely to be identified with or incident to the production of a single product. They are the common costs that are incurred to stand ready to produce. The techniques of allocating these common stand-by costs of products are what we usually think of as cost accounting. Essentially, the problem is one of distinguishing between the cost of idle capacity and the cost of utilized capacity. The costs of idle capacity are not considered properly chargeable to products; the proportion of stand-by costs, however, that represent utilized capacity must be reasonably and equitably divided over the products that are produced. This is perfectly reasonable and logical for purposes of income determination. It is not reasonable and proper for other objectives.

Many of the most significant decisions in businesses are concerned with the evaluation of alternative courses of action. Here again, the objectives are different and the nature of true costs must be derived from objectives. When we are considering dropping a product, we are interested in its profit contribution and the stand-by cost that might be eliminated because we are no longer in the business of producing and selling this product. Dropping this

product could conceivably cause a reduction in the sales of other related products and, in this case, those lost sales would be a cost that we should consider in evaluating this alternative.

The objectives for the use of cost in profit planning are almost identical with the objectives in cost control. The problem is one of saying what are allowable amounts of expense. In planning, however, we are concerned with establishing a plan at a given level of activity. In other words, this is our goal in terms of volume that we want to achieve. Therefore, we are really concerned with only the allowable amount of expense at that level. In cost control, we must know allowable amounts of expense at many levels because we may exceed our planned sales or else fail to meet the planned level of activity.

THE PROFIT PLAN-*INTEGRATES SUBSIDIARY PLANS*

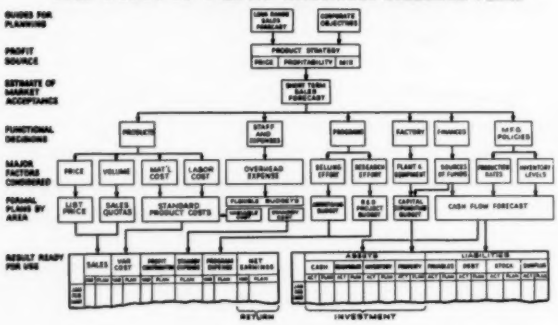


Exhibit VI

Exhibit VI on profit planning serves to orient the control of overhead expenses into the total picture of profit planning. A profit plan is basically a compromise between two elements. On the one hand, what do we want to achieve? - what are the corporate objectives? On the other, what are the possibilities of being able to accomplish these objectives? What are long-range sales and economic forecasts? Within these two limits, we attempt to develop a strategy for the short term. This short term strategy must be translated in terms of product, people, costs, programs, plant, capital funds, and time schedules. In developing this strategy, many alternative courses of action must be considered, and costs will be considered from many different viewpoints. Once a plan of action has been determined, this plan can best be expressed in terms of planned results of operation and planned financial positions at various points of time.

Because accounting within such an integrated framework is unique, we have given it the special name of Profitability Accounting. As indicated in Exhibit VII, the responsibility

PROFITABILITY ACCOUNTING AND CONTROL

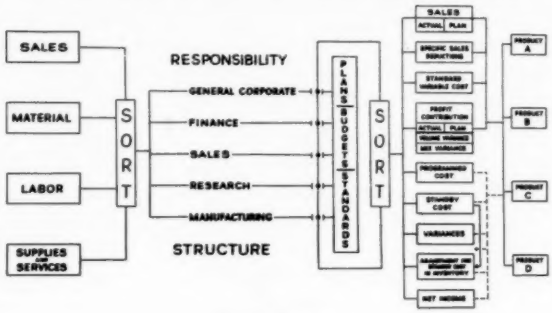


Exhibit VII

structure is the main framework of Profitability Accounting. Incremental costing and profit contribution are major elements. Within the profitability structure, systems designed to achieve different objectives are integrated as much as possible without sacrificing any of the objectives. Where data used for one objective seems to be in conflict with similar data used for another objective, means are provided for reconciling. Decision-making data is related to the decision-making structure of the business with the intention of providing management with the best information for making plans and decisions.

CONTROL AND FEEDBACK THROUGH PROFITABILITY ACCOUNTING

Even if we get all of our logic straight and our integrated systems generate the data relevant to each of the various objectives, the system's effectiveness as a management tool will depend in large part upon the quality of the reports generated by the system.

The reports in Exhibits IX through XIII are typical of the kind of reports that can be generated by a Profitability Accounting system. The exact nature of the report for a particular company depends upon the nature of the

particular company. Management reports must be tailored to the personnel, systems, and policies of each organization. Effective reports must reflect the operating climate and the objectives of the business. It should be understood from the outset that reports do not control performance. Reports do not make decisions. Reports do not make profits. The best we can hope for from a report is to have a report reveal problems and guide the manager in knowing what questions to ask and to whom to ask them. The report should provide information relevant to the problems of the person who reads it.

The reports that we will look at are from the Vortex Manufacturing Company. It is a multi-product, multi-plant operation. The firm manufactures refrigerators in a completely separate integrated division according to the organization chart in Exhibit VIII. This division is responsible for its own sales and its own manufacturing. It is comparable to a wholly-owned subsidiary. The Electronic Division of the firm manufactures television sets and radios. Sales of this division are both to the military and to industrial markets. Television sets and radios are both manufactured in the same plant using common processing. Exhibit IX is a consolidated statement of net earnings for all divisions for the month of April. April is a good month. Net earnings are $13,000 better than plan for April; $35,000 better than plan year to date, and we anticipate making $2.03 per share for the year representing a 7.3% return on investment which is also slightly better than plan.

These favorable results are attributable to three factors. First, sales are running $974,000 ahead of those anticipated this year to date. These additional sales, of course, give us additional profit contribution - some $234,000 year to date (see box in lower left-hand corner of Exhibit IX). More than this, we are selling a mix of products that has a higher profit contribution rate than the average anticipated. The rate is only two percentage points better than plan for the year, but that is equivalent to $514,000. Third, we have also experienced favorable budget performances as indicated by the $187,000 favorable variance in April and those in prior months.

This report is designed to emphasize

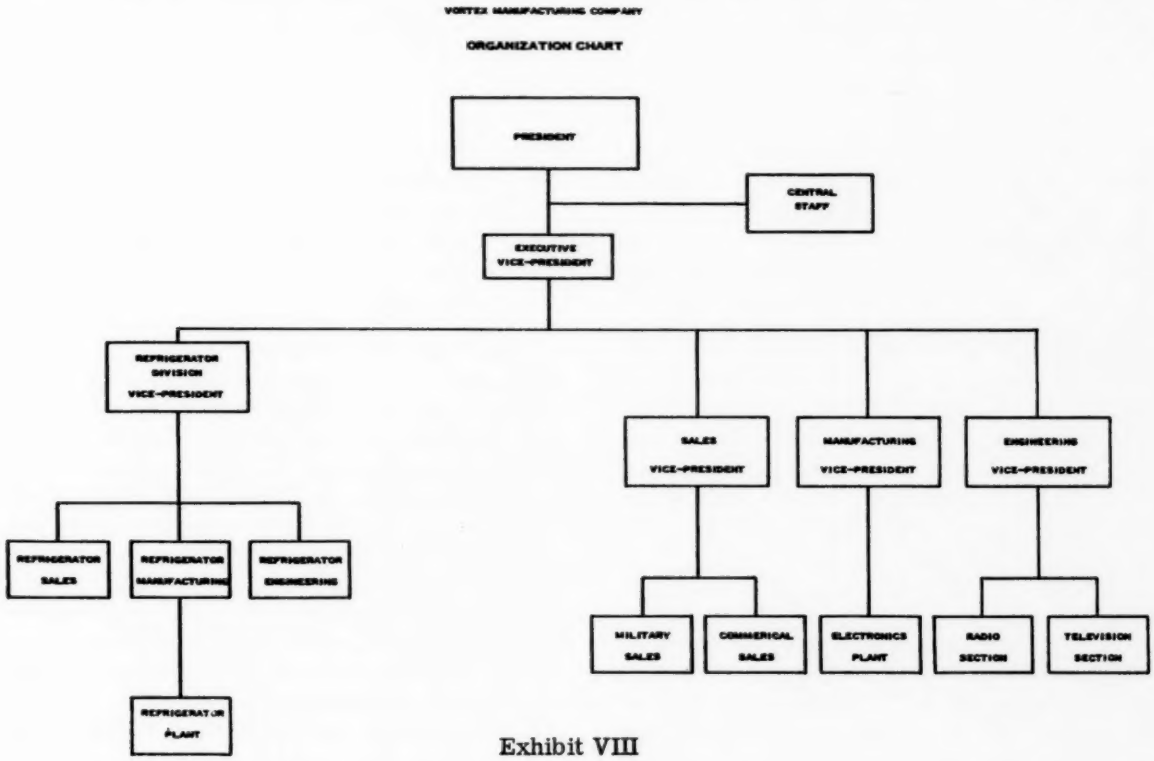


Exhibit VIII

VORTEX MANUFACTURING COMPANY

STATEMENT OF NET EARNINGS

(DOLLARS IN THOUSANDS)

Month	Gross Sales		Standard Profit Contribution				Expenses			Operating Earnings Before Taxes		Bonus and Profit Sharing		Net Earnings		Earnings Per Share	Month
			Amount		Per Cent Sales		Variances	Standby	Programmed								
	Over (Under)	Actual Plan*	Over (Under)	Actual Plan*	Over (Under)	Actual Plan*	Actual	Plan	Plan	Over (Under)	Actual Plan*	Over (Under)	Actual Plan*	Over (Under)	Actual Plan*	Actual Plan*	
Jan	(225)	3,750	(190)	1,073	(3.2)	28.6	105	850	249	(85)	79	(17)	16	(7)	31	.02	Jan
Feb	237	5,035	205	1,432	2.8	28.4	98	852	284	303	394	21	79	9	160	.13	Feb
Mar	483	6,458	386	1,758	4.3	27.6	173	858	307	559	766	43	153	20	304	.24	Mar
Apr	479	8,155	347	1,879	3.1	23.0	187	856	385	534	825	32	165	13	337	.27	Apr
May		5,991*		1,617*		27.0*		855	245		517*		103*		211*	.17*	May
Jun		6,348*		1,775*		27.8*		855	50		870*		174*		343*	.43*	Jun
Jul		6,262*		1,712*		27.4*		855	277		580*		116*		209*	.17*	Jul
Aug		7,111*		1,927*		27.2*		856	324		747*		149*		292*	.24*	Aug
Sep		6,804*		1,854*		27.2*		856	372		626*		125*		225*	.18*	Sep
Oct		5,305*		1,527*		28.9*		855	237		425*		87*		158*	.13*	Oct
Nov		5,413*		1,511*		27.9*		856	276		379*		76*		139*	.11*	Nov
Dec		5,354*		1,498*		28.1*		858	327		313*		63*		107*	.09*	Dec
Year To Date	974	23,398	748	6,142	2.2	26.2	563	3,416	1,225	1,311	2,064	79	413	35	832	.66	
Original Plan		71,012		18,815		26.5		10,262	3,333		5,220		1,227		2,481	2.01	
Current Forecast		71,986		19,563		27.2	563	10,262	3,333		6,531		1,306		2,516	2.03	

Volume and Mix Variance	This Month	Year to Date
Planned Profit Contribution	1,532	5,394
Volume Variance	95	234
Mix Variance	252	514
Actual Profit Contribution	1,879	6,142

Return on Assets	Original Plan	Current Forecast
Average Corporate Assets	34,500	34,500
Capital Turnover	X	
Return on Sales	3.5%	3.5%
Return on Assets Employed	7.2%	7.3%

(*) INDICATES UNFAVORABLE VARIANCE OR LOSS

Exhibit IX

deviations from plan. It keeps us thinking about the objectives that we have intended to accomplish. It shows clearly our present position relative to these desired goals. The current forecast for the remainder of the year is an index of the probability of reaching that goal. The information given us in this report also suggests that maybe we should look at current and projected economic conditions and perhaps revise our goals in the light of what we may find there. The position indicated in this report is certainly favorable, but it could be that it is not as favorable as it really should be in relation to the economic situation being enjoyed. When we decide that this is the case, we will revise our current forecast for the year and perhaps our plan.

Exhibit X is a Division Earning Statement for the same period of time for the Refrigerator Division, the independent division, if you remember. An examination of this report will reveal that this division certainly is not experiencing the favorable variances being enjoyed by the company as a whole. It should be noted in this report that stand-by expenses are divided into two categories - specific and general. The specific stand-by expenses are those stand-by expenses which are incident to the existence of this division. They would be eliminated if this division were eliminated. These stand-by expenses represent the period cost of plant and equipment, of supervision, and other such ready-to-serve categories of cost. The general stand-by costs, on the other hand, are simply the share of general corporate stand-by costs that this division manager has agreed to attempt to swallow. These stand-by costs are accepted by him for a period of time; perhaps the basic decision is made over a five-year period. They are not lowered if this division experiences a decline in volume. They are not raised if this division experiences

VORTEX MANUFACTURING CORPORATION

DIVISION STATEMENT OF EARNINGS

REFRIGERATOR DIVISION

(DOLLARS IN THOUSANDS)

Month	Gross Sales		Standard Profit Contribution				Standby Expenses		Programmed Expenses	Standard Product Line Earnings	Division Expense Variances	Division Operating Earnings		Orders Received		Order Backlog	
			Amount		Per Cent Sales												
	Over (Under)	Actual Plan*	Over (Under)	Actual Plan*	Over (Under)	Actual Plan*	Specific	General			Actual	Over (Under)	Actual Plan*	This Year	Last Year	This Year	Last Year
Jan	(231)	1,266	(89)	328	(2.0)	25.9	54	270	105	(101)	(15)	(104)	(116)	371	601	1,315	749
Feb	(102)	1,830	(41)	490	(0.8)	26.8	54	270	120	46	2	(39)	48	972	1,100	1,511	1,269
Mar	(10)	2,609	(4)	749	(0.1)	28.7	57	273	108	311	(26)	(30)	285	1,241	1,301	1,427	527
Apr	(45)	2,331	(16)	683	(0.1)	29.3	57	273	120	233	(13)	(29)	220	622	727	1,311	608
May		1,860*		489*		26.3*	57	273	84	75			75*		711		371
Jun		2,193*		645*		29.4*	54	270	3	318			318*		1,921		1,006
Jul		2,109*		591*		28.0*	57	270	96	168			168*		1,875		1,137
Aug		2,145*		618*		28.8*	57	273	90	198			198*		992		1,192
Sep		2,508*		708*		28.2*	54	273	108	273			273*		1,176		1,187
Oct		1,932*		534*		27.6*	57	270	105	102			102*		1,483		1,389
Nov		1,419*		417*		29.4*	57	270	81	9			9*		1,519		908
Dec		1,290*		378*		29.3*	54	273	105	(54)			(54)*		1,633		1,579
Year To Date	(388)	8,036	(150)	2,250	(0.5)	28.0	222	1,086	453	489	(52)	(202)	437	3,206	3,729		
Original Plan		23,880		6,780		28.4	669	3,258	1,125	1,728			1,728				
Current Forecast		23,492		6,630		28.2	669	3,258	1,125	1,578	(52)		1,526				

Volume and Mix Variance	This Month	Year to Date
Planned Profit Contribution	699	2,400
Volume Variance	(14)	(110)
Mix Variance	(2)	(40)
Actual Profit Contribution	683	2,250

Return on Assets	Original Plan	Current Forecast
Average Division Assets	14,431	14,140
Capital Turnover	1.65	1.66
X		
Return on Sales	7.2%	6.5%
=		
Return on Assets Employed	11.9%	10.8%

Exhibit X

an improvement in profit. These costs are not related to the activity of this division or any other division. Many companies make the mistake of cancelling out the gain of one division by tying general corporate stand-by costs to the sales volume of a division. Just as soon as the division starts doing good, it starts looking worse because the home office is giving it more costs. The ones that are not doing so well look better. This is ridiculous, but common. The programmed expenses shown in this Division Earning Statement are special programs being undertaken by this division that are not related to volume and are not recurring. A special institutional type advertising campaign for this division might be that kind of expenditure. A general plant improvement program might also fall into this category.

Over-all, we can see that the responsibility units of this division have spent $13,000 in excess of allowable amounts of expenditures during April.

Exhibit XI shows who is responsible for this $13,000 unfavorable variance. Of the three major units of the Refrigeration Division, we can see that T. Sawyer, director of manufacturing, is responsible for both the largest amount and the largest percent variance from budget. Within his unit, it is the Plating Department that is the major culprit.

Notice that in these reports extraneous details that can interfere with communication have been eliminated. Each of the figures shown, for instance, is in terms of significant digits. The last three dollar digits and the cent digits are not reported. Because of the purpose of this report and the magnitude of the figures involved, we care very little whether Mr. Wilde down in the Plating Department is $12,200 or $12,600 in excess of this budget. The last three digits are not decision-making information.

Exhibit XII is a detailed comparison of

VARIANCES - TRACKED TO SOURCE

REFRIGERATION DIVISION

(DOLLARS IN THOUSANDS)

Month	TOTAL DIVISION		T. SAWYER MANUFACTURING		O. HENRY SALES		C. PORTER ENGINEERING		Month
	Amount	% Budget	Amount	% Budget	Amount	% Budget	Amount	% Budget	
Jan	(15)	10	22	28	7	9	(4)	(4)	Jan
Feb	2	9	20	25	4	5	(2)	(2)	Feb
Mar	(25)	2	5	6	(2)	(3)	1	1	Mar
Apr	(13)	(1)	(6)	(6)	(3)	(4)	(4)	(1)	Apr
May									May
Jun									Jun
Jul									Jul
Aug									Aug
Sep									Sep
Oct									Oct
Nov									Nov
Dec									Dec

MANUFACTURING EXPENSE VARIANCES - BY DEPARTMENT

Month	T. SAWYER TOTAL PLANT		J. BELL PRESS		O. WILDE PLATING		G. TORY ASSEMBLY		Month
	Amount	% Budget	Amount	% Budget	Amount	% Budget	Amount	% Budget	
Jan	22	28	6	24	5	13	11	73	Jan
Feb	20	25	5	20	3	8	12	80	Feb
Mar	5	6	(1)	(4)	(3)	(8)	9	60	Mar
Apr	(6)	(6)	4	16	(12)	(3)	2	13	Apr
May									May
Jun									Jun
Jul									Jul
Aug									Aug
Sep									Sep
Oct									Oct
Nov									Nov
Dec									Dec

( ) INDICATES UNFAVORABLE VARIANCE

Exhibit XI

actual performance against allowable performance for the Plating Department. This report is prepared both for use by Mr. Wilde in evaluating his own position and also for the plant manager as an index of Mr. Wilde's performance.

This detailed report shows that the $12,000 unfavorable variance is the result of a direct labor variance that was $6,000 in excess of an anticipated labor variance, $9,000 of unplanned overtime, and a $3,000 favorable manufacturing expense variance. Although the over-all variance is relatively small, individual items within this category represent significant departures from allowable performance. Indirect salaries, set-up labor, and maintenance labor are particularly out of line. Dollars of variance may not mean too much to Mr. Wilde; therefore, these dollar figures are supplemented by a manpower statistics box in the lower left-hand corner of the report. Here Mr. Wilde has shown his labor variance in terms of people. There were 13 direct labor people in excess of normal requirements and 25 hourly indirect people in excess of those allowed by the manpower table associated with the flexible budget. There was an excess of 6 salaried people. This is the kind of information that Mr. Wilde can act upon.

The manufacturing manager wants to know what Mr. Wilde is going to do about these departures from acceptable performance. Exhibit XIII is an example of a variance letter prepared by Mr. Wilde to explain material departures from the flexible budget. The items that he decides to explain should be determined by company policy. For instance, he might be required to explain all variances in excess of $1,000, or he might be required to explain all variances that were in excess of a given percentage of the budget. In reviewing his report, it is noted that he does not explain any of

DEPARTMENTAL REPORT

BUDGET PERFORMANCE – BY EXPENSE ITEM

Month of April
Level of Operation 80%

PLATING DEPARTMENT – O. WILDE

(DOLLARS IN THOUSANDS)

Expense Item	This Month			Year to Date		
	Performance Variance		Actual Expense	Performance Variance		Actual Expense
	Amount	% Budget		Amount	% Budget	
Indirect Labor						
Salaries	(4)	(17)	27	(19)	(18)	122
Material Handling	3	25	9	6	13	40
Setup	(2)	(100)	4	(7)	(64)	18
Inspection	2	40	3	3	19	13
Maintenance	(11)	(17)	78	(29)	(7)	317
Other	(6)	(300)	26	(22)	(25)	107
Indirect Labor – Total	(18)	14	147	(68)	(12)	617
Overtime Premium (Indirect)	(2)	(40)	7	(7)	(29)	31
Fringe Benefits	4	22	14	(22)	(61)	58
Indirect Material						
Perishable Tools	1	33	2	2	22	7
Maintenance	11	14	70	24	8	286
Other	(2)	(50)	8	(9)	(50)	27
Indirect Material – Total	10	11	78	17	5	320
Other Expense	9	23	29	39	25	117
Total Manufacturing Expense	3	1	275	(41)	4	1,143

MANPOWER STATISTICS – AVERAGE FOR MONTH

Numbers Of People	Variance	Actual
Direct Labor	(13)	335
Hourly Indirect	(25)	212
Salaried	(6)	47
Total	(44)	594

DIRECT LABOR STATISTICS

Dollars	This Month			Year to Date		
	Variance	% Budget	Actual	Variance	% Budget	Actual
Standard Direct Labor	—	—	173	—	—	892
Direct Labor Variance	(6)	(25)	30	46	60	122
Overtime	(9)	—	9	(12)	—	(12)

( ) Indicates unfavorable variance

Exhibit XII

the favorable variances. The plant manager may very well challenge this decision.

CONCLUSION

A fundamental feature of overhead cost control under Profitability Accounting that has been presented here is that the control system must be tied in with the general accounting system and not independent of it. As a by-product of departmental and responsibility expense control, it also produces departmentally or functionally summarized variable, stand-by, and programmed costs which are useful for purposes of product costing, statement presentation, and various management decisions. The system permits no measure of disagreement on fundamental principles of accounting as between financial accounting requirements and managerial needs for information.

In Profitability Accounting, it is also assumed that reports to management must be in a language which is understandable and readily convincing to profit-minded managers as well as being meaningful to accountants. It must be alive and conducive to effective decision making at all levels. Incremental costs and profit contributions are vital considerations in just about all management decisions that involve figures. For that reason, these concepts must pervade the entire framework of control techniques within a company.

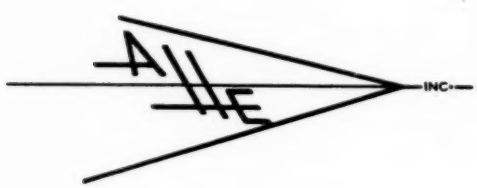
SUPERVISOR'S EXPLANATION

VARIANCE LETTER

EXPENSE ITEM	AMOUNT (IN THOUSANDS)	EXPLANATION OF VARIANCE	CURRENT CORRECTIVE ACTION
SALARIES	(4)	SALARY FORCE WAS INCREASED TO EXPECTED 100% LEVEL, BUT ACTUALLY OPERATED AT 80%.	SALAR. FORCE CUT BACK TO OPERATING LEVEL TO FIT CURRENT OUTLOOK.
SETUPS	(2)	COST OF WORKING ALL SETUP MEN EVERY SATURDAY DURING MONTH FOR NECESSARY EXTRA LINES.	EXTRA WORK COMPLETED.
MAINTENANCE	(19)	PREMIUM DAYS WORKED TO REPAIR UNITS CAUSING DOWNTIME, THUS CREATING MORE BACKLOG ON BALANCE OF MAINTENANCE WORK.	THIS AREA IS BEING WATCHED CLOSELY.
OTHER	(6)	EXTRA MANPOWER NECESSARY TO REMOVE PURCHASED MATERIALS FROM FREIGHT CARS, AND MOVE MATERIALS INTO HOPPER.	TEMPORARY SITUATION, CORRECTED IN MONTH OF CHARGE.
OVERTIME PREMIUM	(2)	SETUP AND MAINTENANCE WORKED SATURDAYS DURING MONTH.	NO OVERTIME IS PERMITTED WITHOUT PROPER APPROVAL. EVERY ATTEMPT IS BEING MADE TO HOLD THIS CHARGE TO A MINIMUM.
OTHER INDIRECT MATERIAL	(2)	COSTS OF LUBRICATORS FOR CONVEYORS AND PRESSURE TANKS IN DEPT. 63.	NO HISTORICAL DATA WAS AVAILABLE TO SET BUDGET MORE ACCURATELY. NO ACTION PLANNED.
DIRECT LABOR	(6)	TRAINING OF APPRENTICE WORKERS INCLUDED IN THIS CHARGE.	APPRENTICE TRAINING OVERLOOKED IN SETTING STANDARDS LAST YEAR. EXPECT TRAINING TO STAY SMALL, WILL INCLUDE NEXT YEAR. NO STANDARD REVISION BELIEVED NECESSARY NOW.

SIGNED _____
SUPERVISOR, PLATING DEPT.

Exhibit XIII



PRODUCTIVITY WITHOUT COMPROMISE - THE RUCKER PLAN

by HOWARD E. STRONG
President
STRONG - NAROVEC & COMPANY

Mr. Strong is a graduate of Carnegie Institute of Technology, where he received a degree in Management Engineering. Continued study has been concentrated in the fields of Industrial Relations, Accounting and Economics.

He has been employed by several large manufacturing companies as Industrial Engineer and as Chief Industrial Engineer at both plant and staff levels. Following this experience, he entered consulting work as a staff associate of a large New York consulting firm. After several years with this firm, he resigned in 1947 to organize Strong-Narovec and Company with headquarters in Cleveland. He has been active in many professional groups, has frequently appeared as a speaker at conferences of groups such as: The Industrial Management Society, American Institute of Industrial Engineers, Society for the Advancement of Management, National Metal Trades Association, Midwest Compensation Association, National Association of Cost Accountants, and the Controllers Institute. He has also written and published a variety of technical and Management Reviews pertaining to new developments in his profession.

"PRODUCTIVITY WITHOUT COMPROMISE - THE RUCKER PLAN"

By HOWARD E. STRONG

President, Strong-Narovec and Company

THERE is no doubt that individual incentives have had a great value in increasing production and reducing unit costs in past years. If at the same time these benefits are obtained, other problems are created which offset the gains, then it is time that Top Management, Industrial Engineers and Personnel Directors take a factual appraisal of where they are heading.

There is a long list of compromises that seem to exist in either a minor or major degree in most individual incentive installations. I am not referring to a new program which has just been installed, but to systems which have been in operation for periods of two or three years or longer.

If your Company is now using individual incentives, it is possible one or more of the following compromises have been made in your plant:

1. You have obtained increased production of unit output, but the increased work pace has resulted in excessive use of raw material and shop supplies. This increased material usage is often ignored, but in many cases it completely offsets the gains achieved through increased production.

2. Increased pace generates poor quality, costly re-work and customer returns. Again, the dollar cost of re-work or scrapped product frequently *more* than offsets any labor saving of individual incentives.

3. After a period of several years of industrial engineering work, you still have a coverage of perhaps no more than 60% of total direct labor hours on individual incentives. This can be caused by a number of factors such as lack of sufficient industrial engineers, short runs or job order products, frequent change of models, product or methods, or union opposition. In a large number of plants there is no incentive coverage at all for maintenance and service labor. If this condition exists, you then have incentive coverage on perhaps no more than 30 to 40% of the total plant labor hours. You started out to install incentives, but for one reason or another have probably been forced to compromise at far less than 100% coverage.

4. The above condition then breeds other compromises which are also far short of the administration your top management would like to achieve. Some of these traps that companies get into, and then wish they hadn't, can go like this:
   a) Due to work schedules, an incentive worker is forced to work on day work temporarily, or no incentive rate exists for the particular operation. He complains that he is losing incentive pay and loafs on the new assignment or perhaps carries his complaint to the grievance stages. The grievances are bad enough, but we have seen some companies who have been forced under union pressure to start paying average incentive earnings for such day rate operations. This kind of compromise can turn out to be very costly.
   b) Another situation that frequently develops because of lack of full incentive coverage, concerns pay differentials for skills and the worth of the job. At one time in your plant, particularly if you had no incentives of any kind, you may have had equitable base rate differentials between different production jobs and between highly skilled maintenance jobs. You

then decide to install individual incentives and after a few years find that take home pay for production jobs has almost equalized, while pay differentials for skills of the job have disappeared. Skilled maintenance jobs present another problem. At contract negotiations, it is not uncommon for the union to demand and obtain extra pay increases for indirect or maintenance workers because they do not have the opportunity for incentive earnings. The union claims incentive production workers are making more money than highly skilled maintenance jobs and the company yields to extra increases for maintenance workers. The following year the union is back again asking *this* time for extra increases for production workers, because last year the maintenance workers got it. This whipsawing is difficult to effectively resist, but is entirely eliminated if you have 100% coverage as provided by group incentive plans.

5. Another major area of compromise concerns existing individual incentives that after a period of years have become badly out of line. This condition can be due to a number of conditions such as an original incorrect standard, creeping changes which after a period of time have caused a loose rate, or a militant union which has made it almost impossible to revise rates. Regardless of the cause, it results in a high degree of dissatisfaction between one worker and another when one has a correct rate but the other has a loose and lucrative rate. If nearly all incentive rates have become loose, it then becomes almost impossible to set correct rates for new products or operations because the union will not accept them.

6. There are other important areas that are far from desirable to management, but the final one I will comment on today concerns "limitation of output" by individual incentive workers. Much as we may dislike admitting this, the condition does exist in many plants. Numerous union members and officers have admitted to me that they are pegging production and could easily increase output by an additional 10% or 20%, if they wanted to. They will not give this extra production because of fear of wholesale revision of piece rates and because of the effects on new rates.

The compromises and shortcomings of some, but not all individual incentive systems, are not intended as criticism or indictment of the Industrial Engineer. There are many conditions beyond his control and for which he is not responsible. They include first of all the greatly increased power of unions which was not present 15 or 20 years ago when individual incentives were thought to be the ultimate answer to increasing productivity. They include precedent and decisions of the past, and to say the least, some of these conditions can make the life of the Industrial Engineer very difficult at times.

Top Management very definitely wants increased production and they are compelled to seek every means of reducing costs. To this end, a proper wage incentive can be of great assistance. However, in recent years there is a growing trend at the level of top executives to wonder if they have 'a bear by the tail', by reason of an outmoded incentive system. Typical of this feeling is a recent letter we received from the President of a company, in which he states: "In every grievance meeting I have attended, 90% of our time was either spent in discussion of inaccuracies of our standards, or management's inability to put the plant on 100% incentive coverage. I have therefore come to the conclusion that our present incentive system has too many shortcomings".

I would now like to present an explanation of a new group incentive plan that in recent years has achieved a remarkable success in increasing productivity, reducing union grievances and stimulating greatly improved cooperation between the employee group and management.

This plan is called THE RUCKER SHARE OF PRODUCTION PLAN. It is a copyrighted plan and was developed by Allen W. Rucker, President of the consulting firm of The Eddy-Rucker-Nickels Company of Cambridge, Massachusetts. It is engineered in this area only by our own consulting firm of Strong-Narovec and Company, who is licensed to use the system.

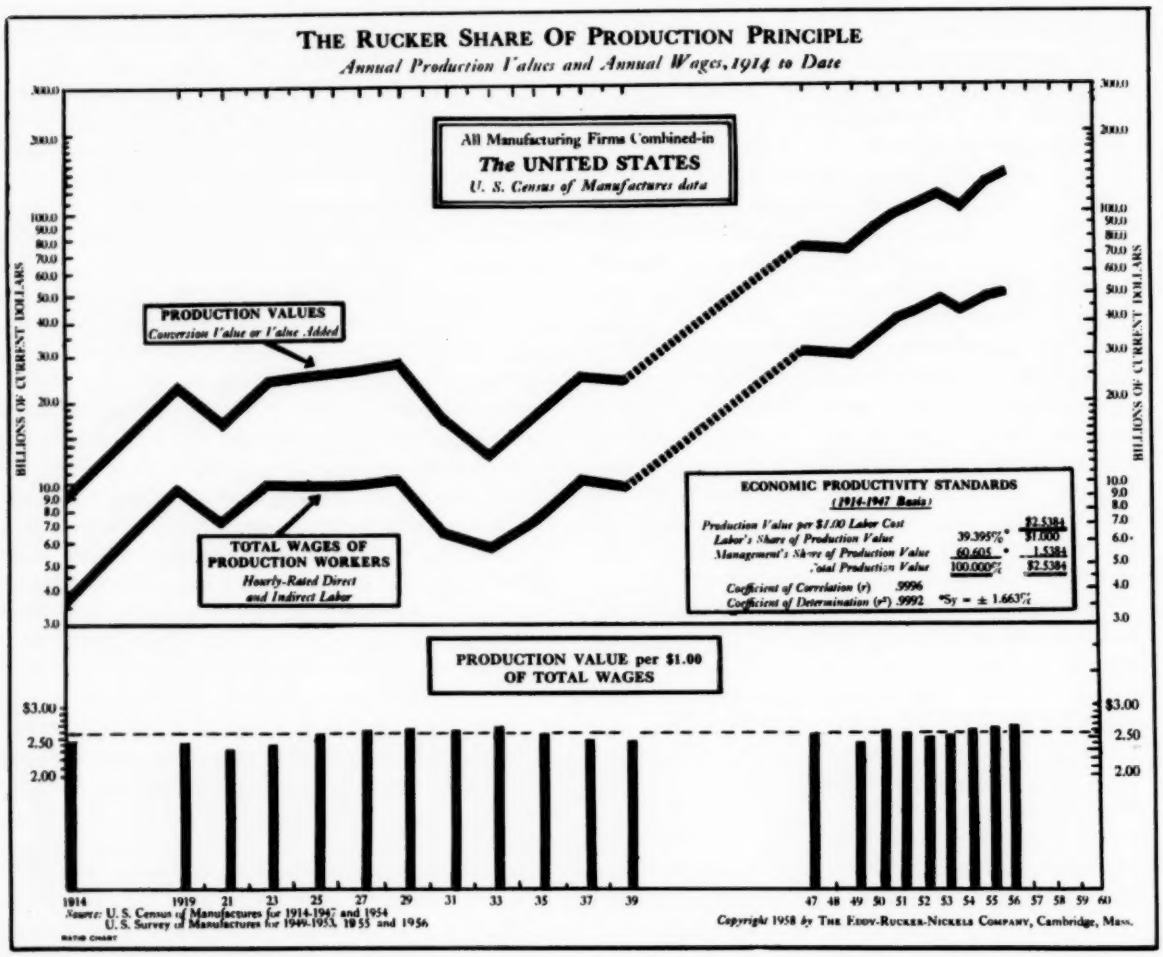
From the original concept, the Plan has had a gradual evolution, with many new refinements and improvements within the last five years. The Plan itself, and the experiences of companies using the Plan have been widely reported in new industrial engineering text books and business magazines.

Our firm has been installing the Rucker Plan for the past nine years. A large number of companies are now using the Plan on both job shop and repetitive work. It can be applied to any type of manufactured product. There are many installations of the Plan, including companies in England, Canada, and West Germany. Companies of almost every size are now using the system.

Under this Plan as applied to hourly-rated workers in manufacturing industries, a prior and currently applicable historical relationship is accurately established between the total earnings of hourly rated employees alone, including fringes, and the net production values actually created by the plant. This relationship is determined at least to two or three decimal points. The management and workers accept this split of production values created subject to the later necessity for re-engineering in cases of major changes in the product or processes of the plant. Thus the total plant pay will rise automatically with an increase in production values, i.e. the productivity of the plant in dollars. The company and the workers will share the increases in the production values which result from their joint efforts, in the same manner that economic engineering analysis has shown had previously existed unbeknown to them all.

Some important advantages not found in other plant wide plans are as follows: the "Rucker Plan" percentage is non-negotiable with a union. It does not require Treasury Department approval since it is not profit sharing and the computations, payoffs, or deficits under the Plan are not determined by the profit level of the company. No users legal counsel has held that the Plan requires stockholders approval prior to application. In the possible eventuality of wage controls and salary controls by the U. S. Government, similar to those set up during World War II and the Korean War, employees will still be eligible for added earnings in line with their proven economic productivity, without modification of the Plan as it was originally installed. During both occasions, wage stabilization boards approved the "Rucker Plan", as conforming to the non-inflationary rules that existed. And last, but not the least in importance, engineering costs are very much less than a piece rate or standard hour plan and maintenance cost is nearly zero. Under the Rucker Plan we provide 100% incentive for 100% of the employees who are covered in the Plan.

The following chart is probably one of the most important that we will have to show you today because it is an illustration of the economic law on which the Rucker Plan is founded. Under the Rucker Plan we set up a labor share and a management share in order to divide the increase of productivity. How do we set the shares? Mr. Ruckers' original research, better than fifteen years ago and continuing ever since, was based on the study of the U.S. census of manufacturers which is made every two years. Now, this chart does not appear in the manufacturers census report, but all essential figures are in the report. The census was first started in the year 1899. We have checked it back that long and keep it up every year. The economic law that I am talking about states that wages when taken as a percentage of production values, tend to remain a near constant. Notice that I said percentage. Wages have been increased in dollar amounts due to inflation, but wages taken as a percentage of the production values tend to remain constant over a long period of years, as shown on our chart. The upper line illustrates production values and the bottom line represents total wages of the production workers. Since this is a ratio chart, notice the paralleling that we get, proving the economic law that for all manufacturing combined in the U. S., the labor share of production value is 39.395% and the management share is 60.6% with a variation, plus or minus, over all that long period of years of only 1.66%. Since this holds true for all manufacturing combined, it must of necessity hold true for individual industries and individual businesses. Under the Rucker Plan we find out, first of all, whether or not this law is working within a company business. Are you conforming to the economic workings of this law? We then determine what the standard is in your particular business, which will be different for every company. From that we then establish what


THE RUCKER SHARE OF PRODUCTION PRINCIPLE
Annual Production Values and Annual Wages, 1914 to Date
All Manufacturing Firms Combined-in
The UNITED STATES
U. S. Census of Manufactures data
PRODUCTION VALUES
Conversion Value or Value Added
TOTAL WAGES OF PRODUCTION WORKERS
Hourly-Rated Direct and Indirect Labor
BILLIONS OF CURRENT DOLLARS
ECONOMIC PRODUCTIVITY STANDARDS
(1914-1947 Basis)
Production Value per $1.00 Labor Cost $2.5384
Labor's Share of Production Value 39.395% * $1.000
Management's Share of Production Value 60.605 * 1.5384
Total Production Value 100.0000% $2.5384
Coefficient of Correlation (r) .9996
Coefficient of Determination (r²) .9992 *Sy = ± 1.663%
PRODUCTION VALUE per $1.00 OF TOTAL WAGES
$3.00
2.50
2.00
1914 1919 21 23 25 27 29 31 33 35 37 39 47 48 49 50 51 52 53 54 55 56 57 58 59 60
Source: U. S. Census of Manufactures for 1914-1947 and 1954
U. S. Survey of Manufactures for 1949-1953, 1955 and 1956
RATIO CHART
Copyright 1958 by The Eddy-Rucker-Nickels Company, Cambridge, Mass.

we call the labor share. As costs change, the management of a company must adjust prices or they must make other economies in the business to offset increased costs. If they fail to do it, the law is not operating in their business and they are on their way to bankruptcy. You cannot allow your manufacturing margin or your profit margin to gradually disappear.

In our engineering work of developing a Rucker installation, we end up with three standards which are used to operate the Plan. Those standards are the production value for one dollar of payroll. Illustrated here for all U.S. manufacturers as being $2.538. We also have a labor share standard, which for all U.S. manufacturers is 39.395% and the company share which is 60.605%.

A Rucker Plan represents three incentives in one. An incentive to increase production, an incentive to conserve materials, and supplies, and an incentive for better quality control.

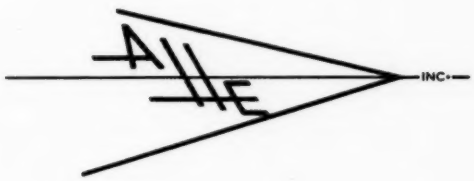
We have a companion plan for the salaried group of people and another plan which was developed in the last two years for any executive group that you would want to include. So, we have three companion plans, one for the hourly, one for salary, and one for the executive group.

The Rucker Plan can be used to replace an existing piece rate or a standard hour plan or can be used in conjunction with your present plan. We have installations where the existing piece work or standard hour plan has been retained and the Rucker Plan put in as an additional incentive to tap the sources of material

savings, to tap the sources of quality control and to get away from the restricted output which piece work rates engender. In some cases the old systems were so out of line that we have abandoned them and substituted the Rucker Plan with excellent results.

* * * * *

(Followed by a visual presentation of operation of the Plan)



INDUSTRIAL ENGINEERING IN RUSSIA

by L. D. "RED" WEBSTER
Vice President
LONE STAR STEEL COMPANY

Attended Dallas elementary schools, graduated Sunset High School, Dallas, 1929. Attended Southern Methodist University three years.

Employed by the Dallas Dispatch as cub reporter. Later became Sports Editor, Aviation Editor, Special Events Editor, Promotions & Public Relations Director.

General Manager, Air Force contract flight school, Cuero, Texas.

Executive Vice President, Red Arrow Freight Lines, Houston, Texas.

Public Relations and Advertising business in Houston, Texas.

Joined Lone Star Steel Company as Public Relations Director. Named Vice President, Employee-Public Relations in 1953.

Member National public relations committee of American Iron & Steel Institute; Public Relations Society of America; International Council of Industrial Editors; American Petroleum Institute; International Economic Affairs Committee of National Association of Manufacturers; Chairman, Labor Relations Committee of the East Texas Chamber of Commerce; Sigma Delta Chi journalism fraternity; National Industrial Advertising Association.

Member Dallas Athletic Club, Press Club of Dallas, Imperial Club. Scottish and York Rites Mason, member Hella Temple Shrine; Methodist.

Author: "I Saw Russia"—1958.

THE RED WHIP

By L. D. "RED" WEBSTER

Vice President, Public Relations - Advertising

Lone Star Steel Company

FROM the pressurized cabin of a DC 7 C, I looked four miles down on a seemingly never-ending forest and tried to convince myself it was no different. Land looks much the same when viewed from 24,000 feet up. You see a general pattern, but not the height of hills nor the depth of valleys.

Below me was a sweeping expanse of timberland that might have been the hills of East Texas, or any one of a dozen other similar areas I had flown over. But it wasn't any of them and no matter how hard I tried to brush away the thought that there was something peculiarly ominous about this woody country below, I knew it was different. Down there, partially shrouded in a smoky, cloud-flecked haze was the Soviet Union, home of the Communists, Red Russia!

Here I was, after weeks of preparation, beyond the Iron Curtain, over Russia, and in a short time I would set foot on the Red soil of the Moscow airport.

"Why," I asked myself, "was I here?" The question of "why" had been asked me dozens of times by friends after they learned I was going to Russia.

And now, in spite of the dozens of answers I had so flippantly palmed off on my friends, I found myself asking the same question.

I went to Russia as a member of a group of industrial editors and public relations executives. The tour was sponsored by the International Council of Industrial Editors, and although approval for 30 members had been obtained, we finally wound up with only 21 who had an answer to the "Why Go to Russia?" bit that was strong enough to produce action instead of wishful thinking.

I went to Russia because I wanted to see for myself what is taking place in this strange land. I've been an avid reader on the subject, and there were many conflicting impressions. One writer brushes the whole thing off as a huge joke. Another is certain the Ruskies will soon rule the world. One chides the Muscovites for their atrocious table manners, another sings the praises of their scientists. How could Paul Robeson and his gifted voice fall so completely under the spell of the Red banner, and how could a lean, lanky Texas piano player, Van Cliburn, invade Moscow and unheralded, sweep the entire nation before him? How much of the stuff in the newspapers and magazines is State Department inspired, and how much of the copy written behind the Iron Curtain is censored by the Russians?

The answers to these questions I wanted to dig out for myself. These answers I wanted to bring back to my friends and say, "Here is the straight dope. I saw it with my own eyes." I wanted to see a real, flesh-and-blood Russian. I wanted to talk to hundreds of them -- and I did. I wanted to talk to card-carrying members of the Communist party. I did. I wanted to see the vaunted Russian education system. I did, from day nursery through grammer and high schools, and finally, the palatial University of Moscow. I wanted to amble over a Russian farm to inspect a Russian factory, to talk to Russian writers and publishers, to see a Russian church. I did all of these things and more.

In the fading light of an Indian summer day, the four engines of the Seven Seas flagship hummed monotonously as the miles sped by. In little more than an hour, the giant bird would glide to a halt at the Moscow airport and I would be at the end of one trail, the beginning of another that would carry me more than 5,000 miles across the land of the Communists, to the principal cities of the Soviet Union, to small towns, on rivers, by train, by car, and by plane.

In the full realization of the opportunity

ahead of me, I resolved that I would spend night and day probing and asking, searching and seeking, listening and looking for the answers to my questions. Is Russia all it's cracked up to be, or is the red paint peeling?

As the plane rumbled on into the growing dusk, the first inkling of our nearness to Moscow came when the stewardess gathered up all newspapers and magazines. Then she passed a tray containing hard candies. The seat belt light flashed on, and below, the night-shrouded earth began to twinkle ever so little.

My first glimpse of the Russian capital was a far cry from the garish extravaganzas of dazzling white lights and multi-color neons that characterize American cities at night. Moscow was more like a sleepy midwestern town at 4 a.m., when only a scattering of street lights continue to burn, when highways and streets are shorn of the lacy ribbons of automobile headlights. Moscow looked gloomy and darkly forbidding. There was a mottled effect given off by yellowish clumps of lights which I later learned were housing projects concentrated around factories. There is no broad sweep, such as an American residential district presents. Russian housing generally doesn't consist of individual homes. Instead hundreds of families reside in huge "workers' flats."

As the pilot circled for a landing, I could hardly believe that we were over a city variously estimated to have a population of six to eight millions. There just weren't enough lights for that many folk, and as the flagship of the Seven Seas probed the night sky, nowhere could I see any set of lights that would mean an airport. Even as the engines were cut and the big bird reluctantly settled for the landing, I could see nothing that resembled a "big city" airport. As the wheels touched down, at the edge of the runway could be seen the pale blue marker lights that guided our pilot.

Going through the Moscow customs was no problem at all, nor was it to be anywhere. Not a bag was opened for inspection at any time during my trip except at New York's Idlewild.

In Russia, all tourists are met at the airport by a representative of the Intourist organization, official agent of the government. Intourist looks after hotel rooms, meals, transportation, and interpreters.

Our initial brush with Russian authority came at the end of our first full day in Moscow. We had spent the day on a tour of several old cathedrals, centuries old, but no longer used for religious purposes. Instead, they are called national museums. In conversations with our guides, I realized that unless something happened, the remainder of our stay in Russia would be pretty much a copy of the first day's treatment.

Before leaving the States, I had been invited to a day long conference with some of my friends at McGraw-Hill Publishing Company, where four senior editors, each of whom had been to Russia, were prepared to brief me on my trip. Mixed in with a vast number of excellent tips on how to get along, they had admonished that I would have to use a great deal of patience and perseverance, and occasionally, might have to bluff a bit. Recalling their words, I walked up to the chief guide at the end of the day and suggested that perhaps tomorrow we might visit a factory.

The guide seemed rather surprised by the request. I then recalled that prior to our departure, we had furnished the Intourist Agency with a long list of the types of activities and enterprises in which we would be interested. The guide answered by saying that this list had been received but such a trip was never offered.

By now, my patience was tried, my perseverance exhausted, so I decided to try my hand at bluffing.

Standing as tall as I could in my cowboy boots, I informed the guide that we had no desire to see any more national museums, that we had come to the Soviet to observe cross-section Russia, that we wanted to see factories, farms, schools, banks, retail stores, and the like, and that if we were not to be permitted this kind of inspection tour, we would simply remain in Moscow, report to the Intourist office each day, until time to return home.

Then, I said, we would shake hands, part the best of friends and leave Russia, BUT when we got home, we would tell our audience of 30 million Americans, that a Russian contract wasn't worth the paper it was written on, the Russians had taken our money, promised us something, then failed to produce. In short, I said, you're a bunch of thieves.

The guide was not impressed, and we took

our leave, saying we would report to the Intourist office the next morning.

The following day, we arrived at the office, and there we sat all day long. It began to look like my bluff had not worked, but at about a quarter to five, the guide came out and advised us that we would be shown a large machine tool factory right in the heart of Moscow the next morning.

Sharply at 9 a.m., the limousines, the guides and the interpretors arrived. We were whisked out to see our first Russian factory. From that point forward, we experienced no difficulty in seeing just about anything we reasonably could expect.

My experiences in that first factory will constitute the bulk of my report to you, for it was there that I secured the first of two copies of actual Russian labor contracts, documents which my McGraw-Hill friends had suggested I try to bring back, and as far as I know, they were among the very first complete labor contracts to reach the U.S. I have had one of them printed in a booklet titled "The Red Whip", which I shall be happy to mail to any of you if you care to give me your name and address following this session.

We had a delightful, and very informative two-hour conference with the factory director, a youngish and obviously quite capable man who had come up through the ranks as an engineer. He answered our questions in a straight-forward manner, and without the hesitancy we later encountered when managers, before answering, would glance toward our Intourist guide for a sign of approval.

Probably our discussions on labor will be of interest to you, for it was here that we first found proof that trade unions in Russia are little more than production whips.

For example, in an effort to ask a lefthand question in hopes of getting a righthand answer, I asked the director "Don't you find it irritating for union officials to try to help you run your business?"

He replied, "I don't know what you mean by using the word 'irritating': I could not run this plant without the help of the union."

It then developed that plant management leaned heavily on the union in disciplinary cases, in meeting production quotas, in handling the assignment of housing facilities, in carrying on an extracurricular program of education, and especially in the development of an esprit de corps linked with loyalty to the government rather than management or the union.

During our discussion of the labor situation, I asked the director if a formal, printed labor agreement was used. When he replied affirmatively, I asked if I might see a copy of it. He ordered an aide to get me a copy, and while the messenger was gone, we launched into other discussions.

After a few minutes, the messenger returned and placed the contract before me. In a sort of aside, I said to the director, "Of course, I can't read this, so would you mind if I keep this copy, and upon arriving back home, I will have it translated and furnish a copy to each of my companions?"

The director said "certainly", and I quickly pocketed the booklet and the discussion continued along other lines.

I should like to emphasize at this point that in none of the factories I visited did I make any particular study of industrial engineering methods. However, I think that my close association with our own industrial engineering department, which at one time was one of my responsibilities, provided me with enough experience to enable me to recognize the presence, or absence, of good industrial engineering practices.

For example, in the field of safety, I was much impressed upon entering the large machine tool factory, to note a huge safety bulletin board. It was quite the most impressive safety board I had ever seen. Measuring about 15 feet wide by at least 10 or 12 feet high, it was equipped with ringing bells, colored transparencies, action, and my first impression was that I was about to see a factory where safety was really a dominant feature of the work.

Imagine my surprise as I walked through building after building and failed to see a single pair of safety shoes, not one hard hat, not a pair of safety goggles. I saw grinding and buffing wheels being operated without guards, and women, wearing smocks with baggy, billowy sleeves that seemed to scream "danger" as these Russian gals operated lathes and other power machines.

So you see, without making a detailed study of any particular activity, it was possible for the trained eye to detect the presence or

absence of sound industrial engineering practices even as it was possible to view an elaborate safety bulletin board and yet fail to find in actual use even the most elementary principles of safety on the job.

This Russian labor contract is an interesting document. In the first place, it is no labor agreement at all. Instead, it is a document, entered into and signed by both management and labor, each assuming the joint responsibility for the fulfillment and overfulfillment of production quotas. It is not a wage agreement reached after long and hard bargaining as we understand negotiations, for this contract makes only one direct reference to wages. It simply says "The wages prevailing in this economic district will be paid."

The very first item in Section 1 of the contract made me wonder about the real progress being made in Russian industry. This item states that the following will be required:

"Increasing gross output in 1958 by 3% over 1957."

Here then, was one of Russia's leading machine tool factories aiming for a gross increase of only 3% despite the fact Soviet industry is operating on some kind of crash basis. In our country, if we went all out, pulled all the stops, I'm sure few of us would be content to settle for a mere three per cent increase.

Now, I would like to read you a number of items contained in the Russian labor contract, and ask you to draw your own conclusions about what is actually taking place. Each of these items will be seen to have some bearing, direct, or indirect, on the application, or misapplication if you will, of industrial engineering. Some of the items are so fundamental they cause one to wonder just what kind of conditions existed before corrective measures were taken.

1. To collect at least 750 suggestions for rationalization throughout the factory.
2. To put into effect not less than 400 such suggestions. (The Russians make no requirements as to the usefulness of a suggestion: they simply say collect 750 and use 400 of them.)
3. The union committee undertakes:
   Systematically, in co-operation with the Administration, to supervise the course of socialist competition, fulfillment of socialist obligations, and to bring the results of the examination to the attention of the workers;

   Jointly with the Administration to publish not later than the 14th of each month the results of socialist competition between departments, shops, brigades and workers by trade during the preceding month;

   Each month to bring to the attention of the entire plant personnel the extent of fulfillment of tasks assigned by the plan;

   To judge and award honarary certificates to victors in the competition and to enter the names of winners in the Honor Roll and Book of Honor. The results of the competition and its winners will be widely disseminated among the workers and employees of the factory.
4. The union committee will organize daily control and will aid the Administration in carrying out the plan for introducing leading methods and organizational and technical measures, the plan for introducing new techniques, producing models of new machine tools, the prompt and high-quality fulfillment of orders for agriculture, consumer goods industry and trade.
5. The union committee undertakes to call regularly production meetings in the departments and shops of the factory and to discuss at them the experience of innovators, problems of improving quality and lowering output costs, introducing new technology and other production problems, to supervise the execution of workers' and employees' proposals, to assist the Administration in carrying out the decisions of production conferences, and to place reports of the Administration before the workers and employees concerning the fulfillment of proposals already adopted.

Now here are a few items which Management agrees to do:

The Administration undertakes to insure re-examination of obsolete and temporary output norms as production is introduced, the acquisition of appropriate habits by workers, the introduction of organizational, technical and business measures raising the productivity of labor.

The Administration undertakes:

To promptly supply workers with special clothing, footwear, and safety devices of

appropriate quality, as well as special food and soap according to the established norms.

To insure the uninterrupted work of sanitary and service units, the supply of soap, towels, and hot water to the showers for all shifts;

To clean the surface of light sources in the shops (windows, light bulbs) at least twice a year and lighting fixtures not less than once a quarter;

To insure a supply of carbonated water to workers in hot shops.

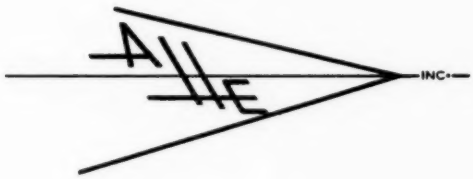
To install forced ventilation in the paint department of Shop No. 2.

Now what does all this mean?

First, I'm certain the Russians are making much progress in their development of industry. They will continue to make progress even as they have progressed rapidly in the race for space. This is possible simply because the Soviet government has the capability of diverting into any given area of activity all of the manpower, brains, equipment, tools, and raw materials needed to do a job. At the moment, Soviet attention is focused upon industry and the conquest of space, the latter, of course, being a relatively small effort when placed alongside the total overall Russian industrial expansion program.

Next, from my own observations and after reading any number of special reports on the Russian's general program, I'm satisfied they are many years behind us, and by the very nature of their effort probably will not in a good many years approach the Free World's standards of efficiency and economy, which are the end results of initiative and incentive, qualities that are not inherent in communism as they are in free enterprise.

This is not to say that the Russians aren't dangerous, that we should shrug them off as a flash-in-the-pan. Far from that, for any country with a population of more than 200,000,000, with a land area of almost eight times the size of the United States, with untold wealth in raw materials, must be carefully observed and constantly watched. There is a Red Menace, but I, for one, am not willing to concede to the oft' repeated communist boast: "Tomorrow, we rule the world!"



INDUSTRIAL ENGINEERING - KEY TO SUCCESSFUL PERSONNEL TESTING

by JEROME H. GIBSON
Supervisor, Personnel Testing and Staff Functions Division
SANDIA CORPORATION

Education: AB (1927) - Holy Cross College - Magna cum laude - majors: Chemistry and Philosophy.

Graduate work: Xavier, St. Louis, Chicago Universities: Humanities, philosophy, education, psychology. Business Manager and Co-Founder: "The Hormone" - publication of Department of Chemistry, Holy Cross College. Associate Editor: "The Modern Schoolman" - publication of Department of Philosophy, St. Louis University.

Professional status: Member, University of Chicago chapter, Sigma Xi; also Divisions of Counseling and Business and Industrial Psychology of American Psychological Association. Also member: American Personnel and Guidance Association, National Vocational Guidance Association, Psychometric Society, New Mexico Psychological Association.

Past experience: Professor of Psychology and Head of Department (1938-46); also, Professor of Personnel Administration (Business Admin. Div.); Professor of Educational Psychology (School of Education); Professor of Guidance (Graduate School of Education); University of Dayton, Dayton, Ohio.

Research Associate, Psychological Corporation of America (New York), 1936-1946.

Coordinator, Engineering, Science and Management War Training Program.

Director of Guidance, Board of Education (1946-1948), Dayton, Ohio. Certificated School Psychologist, Ohio Department of Education.

INDUSTRIAL ENGINEERING - KEY TO SUCCESSFUL PERSONNEL TESTING

By JEROME H. GIBSON

Supervisor, Personnel Testing & Staff Function Division, Sandia Corporation

FOR THIS discussion, "Testing" will be regarded in the broad sense as "measurement of behavior" under standard or controlled conditions, and relates to all industrial activities in which the measurement of behavior is significant.

Psychology, Social Psychology and Sociology with Anthropology are the social sciences primarily concerned with the study of human behavior in the individual, the individual in a group and group behavior. Through the years, more and more refined techniques of measurement have evolved and a whole new era of progress is opening up with the advances made possible by the computer, operations research, programming techniques and cybermetics.

For years, the Psychologists and Sociologists have been unable to resolve the so-called "criterion" problem, viz., establishing the individual and group job and functional correlates of our behavioral measurement techniques. We are asked to measure job qualifications, inter- and intra-group relationships, to study functional and organizational problems, yet even today we are in the dark as to "what" to measure, what job demands, what job and group relationships. No measurement tool is dependable or meaningful without some standard to which it may be calibrated. Yet where job demands are to be measured, we are completely without standards except in very limited areas. A qualified measurement specialist has the tools and knowledge to achieve these objectives successfully, if he knows specifically what to measure and can develop the necessary standards. In my experience, where tests have failed it is either because the person selecting and using them is unqualified or (and usually) the characteristics of the individual or group which is being measured are not really related to or significant to the job or functional situation for which they are being used.

My industrial responsibilities in recent years have drawn me into areas in which Industrial Engineering has made paramount contributions. These have included organizational and functional analysis, human engineering, method study, procedural analysis, job analysis and classification, data processing, and computer programming. This experience has made me realize that the Industrial Engineers' training and experience, while concentrated on the work situation and job demands do not differ greatly from our own. We are both concerned with job behavior and its measurement. We speak the same language: standardization, simplification, sampling, probability, control, calibration, etc. It is as if we both look down one eye-piece of a binocular. The Industrial Engineer sees *Work and Job*, but is concerned with people on the periphery. The Industrial Psychologist and Sociologist sees *People* but has progressed to the point where between his techniques and his objectives is a big wall entitled *Work* or *Job*.

Yet no job, work situation, machine, facility, function or organization can be separated from the people upon whom they depend. "Matching people to jobs" or "machines to people" is not a new idea. The seemingly hopeless criterion problem of those who look through the *People* tube of the industrial binocular is fundamentally the familiar daily task of those who look through the *Job* tube. I hope to demonstrate that by a mutual interchange of attitudes and perspective and through joint effort, Psychology, Sociology and Industrial Engineering can achieve a break-through that with the new techniques and tools available to us will be historic in making available the tremendous unused potential inherent in human resources.

MAINTAINING INDUSTRIAL ENGINEERING FUNCTIONS ON A RESTRICTED BUDGET

by IRVIN OTIS
Manager, Manufacturing Expense Standards
Corporate Manufacturing Staff
CHRYSLER CORPORATION

Mr. Otis holds a BBA in Industrial Management. He has attended courses at the University of Michigan and Wayne State University. He is currently pursuing his master's degree at the University of Detroit.

He has had an extensive background in general industrial engineering practices through association with an international consulting firm and automotive companies.

He is an active member of AIIE as well as the Engineering Society of Detroit, ASM and National Association of Accountants.

MAINTAINING INDUSTRIAL ENGINEERING FUNCTIONS ON A RESTRICTED BUDGET

By IRVIN OTIS

Manager of Manufacturing Expense Standards, Corporate Manufacturing Staff, Chrysler Corporation

WHEN I was asked to present this talk, I found that the subject matter to be discussed is somewhat difficult to pin down in that there is no clear cut design or pattern as to how a Manager of an Industrial Engineering Department can cope with fixed functions, and variable work loads while at the same time compensating for changing conditions and appropriations.

We Industrial Engineers are a "service" organization and, to do our job well, we must be trained and skilled technicians, qualified to perform the duty of analyzing and interpreting data, both historical and current, in a method readily familiar to our associates and in addition, be qualified to make the kind of forecasts which are required in order to render efficient service that our co-workers expect of us.

With this in mind let us now proceed to set some facts before you.

I am sure many of you sitting here today have been faced with the dilemma of cutting your budget and at the same time maintaining an efficient and useful organization. Before we go into this problem in detail, let us first build our plant, that is, let us draw a picture within which we will set our problem and proposed solutions. Let us imagine that we have a company with 5000 to 6000 employees, producing washing machines, dryers, air conditioning and heating units, government defense parts, and automotive parts. This company has one manufacturing location which includes a number of manufacturing buildings housing the following processes:

Stamping
Machining
Die Casting
Plating
Painting
Assembly

Let us also imagine that Industrial Engineering was established in this company five years ago and that much progress has been made during this period. Suddenly, however, business profits being to decline. Why? Many reasons. A minor recession has brought about a slumping consumers market; some of the government work has phased out; but most important, our competitors have been underbidding us. Underbidding us with our automotive business as well as underpricing us in the consumer market. How can they do this and still maintain a reasonable profit? Simple -- just cut costs. Cut costs and you can reduce your prices a commensurate amount.

To reverse the present downtrend of profits and to recapture lost business, top management orders a budget cut -- 18% across the board -- no one is spared in the determined effort to reduce overhead. This may not be the most desirable or effective method of making a budget cut, but these are the orders.

As the Manger of Industrial Engineering you should first take a tranquilizer pill then try to answer the many questions that will come up. What service or function do I cut? Should I reorganize the department? Can I cut 18% and still give the service that I have been giving?

Let's take a look at our hypothetical Industrial Engineering Department. It has a total complement of 47 people and, assuming that the budget cut will be made solely by reducing personnel, it must be reduced to 39 people. Our department consists of:

- An industrial engineer and a secretary
- A supervisor in charge of the Direct Labor Section which includes a stenographer and 20 industrial engineers
- A supervisor in charge of the Indirect Labor and Expense Standards Section which includes a stenographer and 8 industrial engineers
- A supervisor in charge of the Methods Section which includes a stenographer and 11 industrial engineers

I suppose that the easiest way of making the budget cut would be to flip a coin, pick a section, and eliminate it. After all if they are going to reduce the department budget, why not cut a function? Of course, you may not last long with such an attitude but that's one way of doing it. Another way is to pass on the 18% cut the same way it was passed on to you, across the board -- all three sections take an 18% cut. The danger with this thinking is that you may make all three of your sections inefficient. If they were originally manned properly for a specific amount and type of work a cut of 18% is going to mean that nobody will finish their job and the whole department will be inefficient.

What's the answer? Why not apply the Industrial Engineering approach to ourselves? It may be hard to swallow but maybe we should conduct an organizational survey and methodize our own operations. We may have been so busy these years methodizing everyone else, maybe we have slipped up a little ourselves.

The impact of five years of effective Industrial Engineering within the company has undoubtedly changed the environment within which we are operating today. Many services and controls which were once thought mandatory may no longer be required. Before we examine each function, let's look at the overall office operation:

- Does the paper work turned out by the department help anyone, or is it an end job in itself?
- Is it worth the effort to maintain the record?
- Is the record being duplicated within the department or within the company?
- Is the record being kept to protect someone?

Three things should be kept in mind when analyzing your records and files:

1. The paper work must give the facts.
2. Help the job.
3. Merit the effort.

If it doesn't, eliminate it.

Over-all controls and records of the Industrial Engineering hours spent on each activity should be kept so that an analysis of the services rendered may be made periodically. Such an analysis may be made through the use of an "Activity Report" submitted by each Industrial Engineer. (See figure 1)

By consolidating all the individual activity reports onto a "Summary Sheet" the over-all departmental effort may be analyzed. (See figure 2)

Through such an analysis, man-hour requirements may be reduced by:

1. Developing a more effective system for the *scheduling* of *work* and for the establishment of work priority to eliminate the possibility of conflict where assignments compete with each other for completion at the same time.
2. Conducting *periodic* studies of clerical and routine duties to determine whether changing conditions make them non-essential and therefore unnecessary.
3. Determining proper work distribution thereby assuring that each engineer is carrying his fair share of the load.

Now let us examine the functions and responsibilities of each of the three sections within the department.

DIRECT LABOR

The Direct Labor Standard Section is charged with the responsibility of establishing and maintaining accurate work standards for all manufacturing operations, also to make man-assignments and investigate off-standard conditions to improve *current* operator method and work place layouts.

Cost estimating can logically be handled in this section since the basis of most estimating is the Direct Labor costs under either an incentive or measured day rate system. The

WEEK OF 3-17-61.

WORK DISTRIBUTION CHART

INDUSTRIAL ENGINEERING DEPARTMENT

	ACTIVITIES	TOTAL MAN HOURS	I. BELL (ENGR.)	MAN HRS.	B. ROTH (ENGR.)	MAN HRS.	F. FALL (ENGR.)	MAN HRS.	S. GLAD (TYPIST)	MAN HRS.
WORK MEASUREMENT		55								
	STANDARDS		GATHER DATA	6	RECHECK TIME STUDY	6	PLOT DATA	4	TABULATE DATA	6
	TECHNIQUES		REVIEW	3			DEVELOP STUDY FORMAT	7	PROOF READ STUDIES	4
	METHODS		STUDY LAYOUTS	3	STUDY DOCKS & LAYOUT	7	RAIL ANALYSIS	6	TYPE PRELIM. STUDY	3
POLICY PROGRAMS PROCEDURES		34								
	INSTRUCTIONS		PREPARE W/S MANUAL	4	MANUAL FOR SAFETY	5	JANITORIAL PROGRAM	8	DICTATION	2
	FINAL REVIEW				NEW MAN ASSIGN SCHEDULE	4	MANUAL ON T/S	3	PROOF READ	4
	RESEARCH		VISIT LIBRARY	3					TYPE DATA	1
EVALUATION		38								
	BUDGETS						REVIEW MAINT. SCHEDULE	5	CUMULATIVE REPORT	3
	PROJECTS		REVIEW APPROPRIATION PROJECT # 1117	7	NEW PART FOR NEXT MODEL	3	REVIEW WITH COMPTROLLER	2		
	PERFORMANCE		REVIEW PLANNING DEPT.	3	REVIEW MAINT. CRIB	3				
	REPORTS		ANALYZE OPERATING	6	ANALYZE MAINT. DEPT.	4			FILE	2
MISC.		33								
	DEPT. MEETING			1		1		1		
	OTHER		PREPARE EST. FOR PLT. ENGR.	4	CONFERENCE WITH PROD. SUPT.	7	EST. FOR PROD. ENGR.	4	ANSWER PHONE	10
									ATTENDANCE REPORTS	5
		160		40		40		40		40

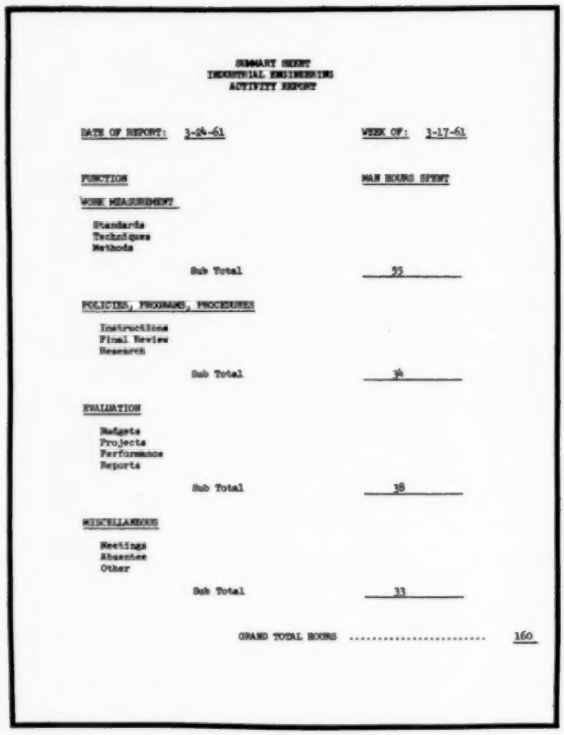
Figure 1

establishment and maintenance of accurate work standards is a must if Direct Labor costs are to be controlled.

Work standards are used for manpower allocations, burden studies, efficiency reports, improvement reports, pricing studies, plant layouts, cost estimating, machine load records, capacity studies, and cost comparisons. The adverse consequences of allowing work standards to deteriorate, in regards to coverage and accuracy, are often underestimated. The inevitable results of an inadequate work standards program is low productivity and corresponding high labor costs.

High labor costs oftentimes force management to take drastic action which may set the stage for serious labor trouble. The cost of work stoppage in terms of slow downs and strikes are well known, yet too often they are the penalty management must pay in order to reverse the trend of declining productivity because of poor work standards. It is obvious then that we cannot arbitrarily curtail the activities of this section without an adverse affect on the over-all production effort. The problem then, is to maintain our output and yet at the same time decrease our input. Traditional and time consuming work measurement techniques such as time study, work sampling and all day production logs must be curtailed and short cut methods must be substituted for developing labor standards.

A formal standard data program supported by charts and graphs and time studies is an excellent substitute. A predetermined time system, such as MTM or Work Factor, is another tool that is gradually being accepted throughout industry.



SUMMARY SHEET
INDUSTRIAL ENGINEERING
ACTIVITY REPORT

DATE OF REPORT: 1-24-61 WEEK OF: 1-17-61

FUNCTION	MAN HOURS SPENT
WORK MEASUREMENT	
Standards	
Techniques	
Methods	
Sub Total	55
POLICIES, PROGRAMS, PROCEDURES	
Instructions	
Final Review	
Research	
Sub Total	34
EVALUATION	
Budgets	
Projects	
Performance	
Reports	
Sub Total	38
MISCELLANEOUS	
Meetings	
Absentee	
Other	
Sub Total	33
GRAND TOTAL HOURS	160

Figure 2

A good training program will teach the foremen the fundamentals of methods and of time study and will prepare him to stand on his own two feet so that the industrial engineer is released for more important jobs.

Designing a data processing program to handle Direct Labor Standards would be another method for facilitating quicker manpower allocation, as well as, facilitating faster cost estimating and cost analysis studies.

INDIRECT LABOR AND EXPENSE STANDARDS

Our second section, Indirect Labor and Expense Standards, is primarily responsible for establishing and maintaining the Manufacturing Expense Budget for authorizing indirect manpower by department and classification at any given volume production; for developing nonproductive materials usage standards; and for controlling other manufacturing expense standards.

This section is rapidly assuming greater importance within industry today. In fact, the increasing need for control in the areas of Indirect Labor and Manufacturing Expense has outstripped techniques and methods necessary for such controls.

This situation has been brought about primarily by the accelerated rate of mechanization during the last decade. Mechanization is basically justified by Direct Labor savings. In some industries and in specific processes the Indirect Labor cost is larger today than the Direct Labor cost. This is primarily due to the highly complex automated equipment and integrated production lines which require more skilled tradesmen, more technicians, more expensive tooling and replacement parts, and more complex maintenance operations.

In other words, the importance of this section increases as new techniques are developed and introduced into industry. Should we then curtail the activities of this section? A section whose importance is increasing with each new technological break-through.

METHODS

The third section, Methods, is perhaps the most important in terms of forward planning and future growth of the company.

In too many instances the operations research facet of this section is allowed to "die on the vine", especially when a budget reduction becomes mandatory.

Too often the Methods Section becomes tied down with repetitive duties such as Materials Handling, Plant Layout and Project Analysis.

Technical Training has been placed under the Methods Section because it is felt that it is easier to train an Industrial Engineer the techniques of teaching rather than teach a training man the techniques of Industrial Engineering in a reasonable length of time.

In view of the importance of this section in terms of future company expansion and success, should we curtail these operations?

The organizational charts to be passed out (see figures 3, 4, 5 and 6) are for the purpose of determining which organizational structure you as Industrial Engineers would choose.

After you have made your selection please pass them forward so that we can tabulate the results and have an open forum concerning the various choices.

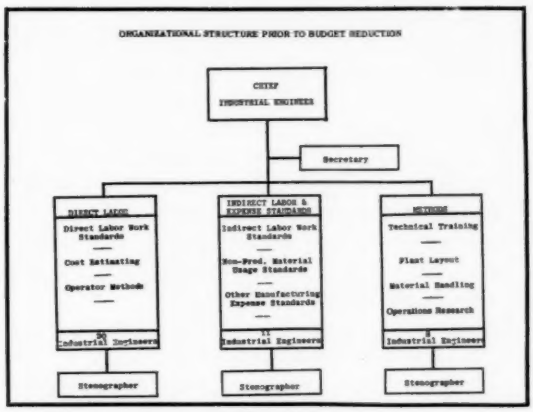


Figure 3

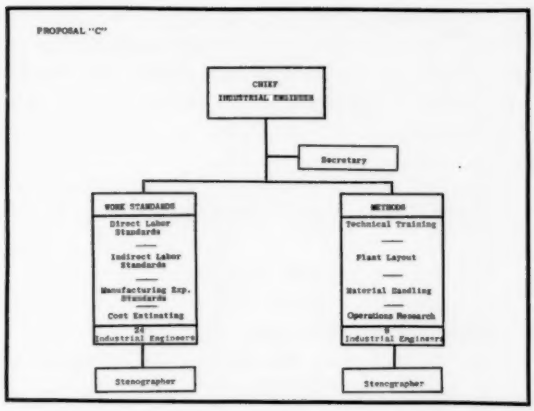


Figure 6

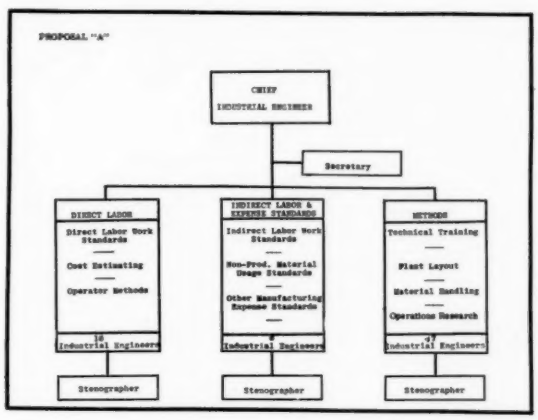


Figure 4

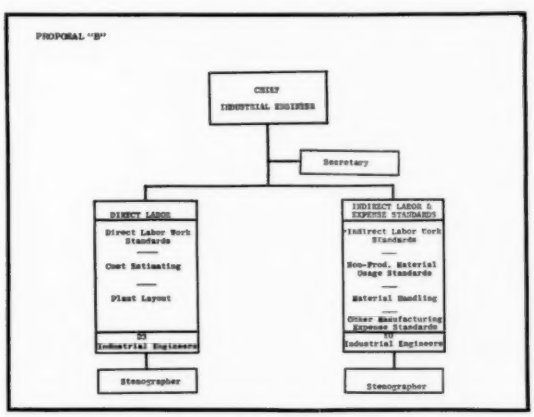


Figure 5

While the results are being tabulated, let us look at the results of a study of the Industrial Engineering activity made by a leading manufacturer as shown on the screen.

I should stress that all techniques utilized in developing work standards and for measuring performance results are to no avail if the organization does not use the control information and planned programs eagerly in achieving the company's cost objectives.

In our profession, you and I, as individuals, must rely on ourselves for the efficient progress of our profession.

We must practice new methods and techniques to make them a part of our personal background.

We must take the initiative in introducing better methods and in planning our proposals before they are presented for acceptance.

Furthermore, we must learn to judge how fast we can move in order to accomplish as much as possible without bringing our planned programs to a crashing halt.

Finally, the dedicated Industrial Engineer can gain maturity and the required perspective by aspiring to the following career development guides:

- Formal education exposure to Financial and other related activities
- Association with professional societies
- Keeping up with the latest practices in the field - periodicals, texts, etc.

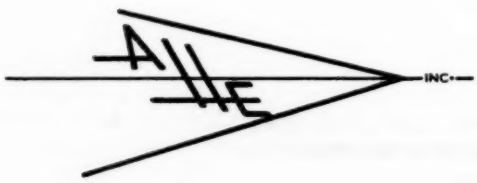
In conclusion I would like to stress the fact that the Industrial Engineering Department is not immune to inefficient practices and should be periodically subjected to an operational review similar to those given to other departments.

Through such a practice the following factors will be kept under control:

- Excessive record keeping
- Excessive clerical effort
- Duplication of effort
- Over-assigning or under-assigning work to Industrial Engineers
- Continued use of outmoded Industrial Engineering techniques
- Time consuming attention to unimportant details as requested by line supervision
- Working on assignments not the responsibility of Industrial Engineering

The Industrial Engineering Department is responsible for advising management of the efficiency of the total operation. We would be remiss in our duties if we did not take all necessary steps to make certain that the technical services of the Industrial Engineering Staff are being effectively utilized.

It is absolutely essential that each of us rethink the present operation of our own department. We must be prepared to prove that Industrial Engineers are not hypocrites, that we practice what we preach.



VALUE ANALYSIS

by **LAWRENCE D. MILES**
Manager, Value Service
GENERAL ELECTRIC COMPANY

Lawrence D. Miles is manager - Value Service, General Electric Company. He was graduated from the University of Nebraska in 1931 with a degree of electrical engineer. He came to General Electric as a design engineer.

In 1938, Mr. Miles transferred to the purchasing department. For four years during World War II, he was assigned as purchasing agent for the Locke Insulator Division of General Electric in Baltimore, Maryland.

In 1947, he was recalled to the Schenectady Office to organize an activity which would bring better value on a wide scale into the use of materials. This activity was called Value Analysis.

With a small group of engineers in General Electric, he has developed methods and techniques which have enabled engineering and manufacturing personnel to eliminate millions of dollars of "non-working" cost from the company's products.

In recognition of this achievement, the company in 1949 presented him its highest award for extra achievement known as the Charles A. Coffin award, given in memory of the Company's first president.

He was - in 1958 - awarded the Navy Distinguished Public Service Award.

Mr. Miles is the recognized authority on Value Analysis and Engineering.

THE VALUE ANALYSIS SYSTEM

By L. D. MILES

Manager - Value Service, General Electric Company

ISN'T Value Analysis another name for Industrial Engineering? This question is so often asked by industrial engineers that we will start with it today.

OBJECTIVES ARE SAME

Basic objectives of both might be approximated as "To prevent or eliminate unnecessary costs."

For comparison, the objective in transportation might be to traverse the distance between Detroit and Toronto. The means used might be an airplane, train, automobile, or bicycle.

Similarly, for the objective, "prevent or eliminate unnecessary costs", different means will exist. Success will result from choosing the most appropriate means for each specific situation. Similarity of objective does not to the slightest degree indicate similarity of approach, of technique, of resources used, or of results accomplished in specific situations.

MANY OF "TOOLS" ARE SAME

Wheels are found on the airplane, train, automobile, bicycle; engines in the airplane, train, and automobile; steel, copper, aluminum, fabric in all. Still they are entirely different products. They do not accomplish the same results in any given situation, nor is one best for all situations.

Similarly, in industrial engineering and value analysis, common parts will be found, sometimes used identically, sometimes used differently, sometimes provided different emphasis.

SAME OBJECTIVE - MUCH IN COMMON - STILL MUCH THAT DIFFERS

Together, let us clearly see that different technologies, like different products, have much in common. The automobile and the airplane have wheels, engines, generators - still the airplane also has wings, emphasizes lightness, emphasizes streamlining, etc., and, as a result, is a totally different product, worthless as a substitute for the automobile in some situations, far exceeding its performance in others.

Similarly the radar equipment and the television equipment have much in common - electric components, oscillator circuits, filter circuits, antennas, etc. Still, each has the addition to its system of a vital few *differing* parts so that the overall is a different product producing very different end results.

The difference in products and in product capabilities in specific situations is created by the difference in *some* of the parts included in the product system.

The difference in technologies and in technology capabilities in specific situations is created by the difference in some of the parts - techniques and special knowledge - included in the technology.

DIFFERENT PRODUCTS OR TECHNOLOGIES ARE IDENTIFIED BY THEIR DIFFERENCES

To be most helpful and to promote the best understanding, I would like to discuss:

1 - the differences
2 - the strengths of each
3 - the limitations of each

However, since your knowledge of industrial engineering far exceeds mine, I can best approach the ideal by confining my comments to the technology of value analysis and value

engineering, perhaps re-stating the three subjects:

1 - areas of "newness" and of emphasis
2 - specific strengths of value analysis and engineering
3 - specific limitations of value analysis and engineering

AREAS OF NEWNESS AND OF EMPHASIS

1 - Dividing all expenditures into costs of
use values
esteem values
no values
2 - Emphasizing function as the only true base for the determination of appropriate costs.
3 - The evaluation of functions in dollars and cents.
4 - Increasing the emphasis on creativity.
5 - Identifying the "stoppers" or roadblocks which prevent value information development and the provision of special techniques to deal with them.
6 - Emphasizing the necessity for promptly using special knowledge, for locating and utilizing functional products. Providing special techniques to better accomplish it.

SPECIAL STRENGTHS OF THE TECHNIQUES OF VALUE ANALYSIS

1 - Basic approach is entirely from the customer's viewpoint. What does the customer want?

Customer wants . . . suitable performance
. . . suitable cost

Suitable performance includes two classes of items:
Suitable use values - which include quality, life, safety factors, etc.
Suitable esteem values - which include attractiveness, shapes, colors, features.

When translated to the manufacturer's language, these "values" become "functions"
Use values become product use functions
Esteem values become product esteem functions

The use functions cause the product to "perform", while
The esteem functions cause the product to sell.

2 - With *functions only* as basic considerations, the approach and techniques promote good answers to the question of how to reliably provide the functions which the customer wants at lowest cost.
Work does not start with such self-oriented considerations as:

How do we want to design it?
What tooling do we have in place?
What in-place know-how should be used?
What materials do we want to use?
Do we want to buy it or make it?

These, and similar considerations, limit original thinking, prevent the creation of the best value alternatives and often result in lost business and closed factories. These considerations are important *after* appropriate values of functions have been determined and are factored into decision-making in the implementation of value alternatives.

3 - The evaluation of groups of functions and of individual functions in dollars and cents saves large amounts of design time and expense, in that it at once rules out many design and manufacturing approaches as being too costly, so that effort is at once channeled into approaches which have the potential not only of achieving suitable performance, but suitable costs as well.

4 - The force on followed-up creativity produces simple, reliable, low-cost solutions not obtainable without this emphasis.

5 - The special techniques for overcoming roadblocks which limit the development of useful value alternatives, used in combination with the functional approach, provide alternatives which are usually simpler, better quality and lower cost than was believed possible.

LIMITATIONS OF VALUE ANALYSIS

Just as securing better performance requires two steps:

1 - Developing practical technical alternatives
2 - Making decisions and taking actions to implement them

So, securing better value requires two steps:

1 - Identification of unnecessary costs--this is done in the design concept, the design, the purchasing, or the manufacturing stages

2 - Making decisions and taking actions to implement them.

Although extremely efficient and effective in the first step - the identification of unnecessary cost - no special techniques or procedures are provided in the area of decision-making and action-taking which control the implementation of value alternatives.

Large amounts of cost, either prevented or eliminated by the use of value analysis techniques, are therefore limited to those areas where the personnel in management, in engineering, in manufacturing and in purchasing are in reality oriented toward the matter of making decisions and vigorously supporting actions which eliminate large amounts of cost.

SOME ORIENTATION INTO THE VALUE ANALYSIS SYSTEM

Let's distinguish between two types of "value", which I will call "use" value and "esteem" value.

For example, the value of my necktie may be about $2. Now, let's separate the $2 into its parts of "use" and "esteem" value. The "use" value to me of this necktie is zero. It has no "use". Its "esteem" value is $2. I must wear it to conform to custom. If I didn't, I'd suffer the loss of more than $2 worth of "esteem". As a comparison, this tie clip with a value of $2 has a "use" function and an "esteem" function. The "use" function--what the tie clip does--could be reliably accomplished by a suitable pin or other simple product that would cost not over one cent. Therefore, we can roughly say its "use" value is one cent and its "esteem" value $1.99. How about the button on the shirt? If it has a total value of one cent, probably nine-tenths of it is "use" value and one-tenth is "esteem" or "appearance" value. A nail, for instance, has an even higher proportion of "use" value, approaching one hundred percent.

The Value Analysis Techniques provide means for establishing the dollar value of the "use" and of the "esteem" portions of the function.

Now let's take a quick look at the so-called relationship between dollar value and cost. The value of this clock is $5. We know this because we evaluate by comparison; we have seen them around, we have bought them. Because we know what it costs, we have given it a value.

Now, let me add more cost to it. I am going to do some work on this clock, adding labor and overhead to it. Do you think that the added cost of the modification will increase the value? Watch carefully! (Smashes clock on floor.) What is the value of the clock now? It's zero, or scrap value, although its cost was increased, by labor and overhead.

Two things we learn from this demonstration:

1 - There is positively no relation between cost and value. The cost has been increased, but the value decreased.
2 - A sound usable base for value is function. The function capability of that clock changed!

Let us, for the time being, use this definition of value. "Value is the lowest cost to reliably accomplish a function"--where function consists of those elements which cause the product to "work" and those elements which cause a product to "sell."

Some of the approaches and techniques which Value Analysis uses are:

1 - Approach.
Clearly and sharply identify and understand the function, beginning with the function of the overall product, breaking it down into the functions of assemblies, then of the subassemblies, etc.

2 - Technique.
Evaluate this function; i.e., assign a dollar and cents figure to it which is the lowest cost to reliably accomplish the required function. This will be determined by a creative search for engineering, manufacturing, and other value alternatives which would reliably accomplish the total function together with the overall costs involved. Obviously, this evaluation will be just as good as the tools and knowledge and effectiveness of the evaluator. For example, for the function of containing 200 gallons of gasoline in a landing craft which has a useful life of eight years, what is the value? Four 50-gallon drums might cost a total of $25, but probably they wouldn't stand the environment. They would need some sort of coatings. As a first guess, let's estimate that the coatings would slightly more than double the cost. Estimate -- $60. Now we have a quick estimated value of $60 for the function. Always do this before finding out how the job is planned to be done, because it will lead to new and startlingly simple, reliable, and lowest-cost solutions. In this case, the specification actually called for specially-fabricated, special alloy tanks costing $529 each. The result was that in this procurement of tanks for 1000 ships, the cost to you and me, the taxpayers, instead of being the expected $520,000 was $80,000 . . . and the function was indeed accomplished by using four drums with appropriate coatings just as on the preliminary evaluations, for $80 each set.

3 - Another and different technique is called, "Blast, Create--then Refine." This means, get a clear mental picture of the function that is required and of the way it is planned to accomplish it. Then mentally blast this down to something that will have only a small fraction of the cost and will only partially accomplish the function or will have some of the attributes needed in the finished product. Next, creatively refine, adding increments of performance, of function, together with their increments of cost, until the product now will accomplish the total job with adequate reliability. This approach sounds simple, but it is amazingly effective. For example, in the gas tanks just used. . . first was the blast to the $25 drums which would not accomplish the total function; next, came a review of what must be done to provide the total function. Then followed the vital, but simple solution—coat the drums -- which added only $55. So now, by the use of this step-by-step technique, the total function is provided with the same reliability for $80 instead of $520.

Eleven additional techniques are learned by the value engineer, each functioning in its own type of situation to cause the development of applicable reliable low cost value alternatives.

One of the major problems in obtaining acceptance of Value Analysis is that men feel toward the value part of their own work as they would feel toward their artistic work in painting a picture. They have done the best they know how, there are no measurements as in "performance" engineering to tell them how good or bad their value is. They feel very emotional, edgy. The thought of anyone making suggestions which affect the value part of their job gives them the same emotions which a painter feels when he hears what he believes to be "untalented people" criticizing his art. To minimize this problem calls for lots of understanding, forethought and care.

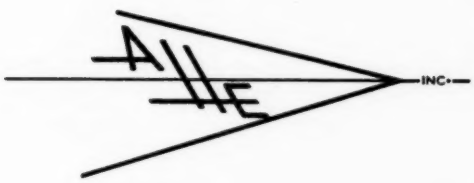
Another major problem is the proper timing of Value Analysis effort. In research and development activities, top-grade "value" work is of great importance but has not been generally so recognized. Research and Development work is substantially performance oriented. Feasibility models are made as fast as possible--the problem is to save time, not to save money. But before the production design is released for quantity manufacture, it needs a large contribution from cost-centered, "value"-oriented engineers. It is too often the case that pressure of time and shortage of value-oriented capabilities forces the subsequent quantity manufacture of "development models", a procedure creating problems in complexity, very high cost, extra weight, and poor reliability. In order to gain time, the value work can be done in the laboratory simultaneously with the performance work.

SUMMARY

The technology of Value Analysis and Value Engineering consists of a system of techniques and of special knowledge which are used in the design concept stage, the design stage, the purchasing stage or the manufacturing stage to efficiently identify unnecessary costs so that they may be prevented or removed.

This technology is function-based and operates to create alternative means for reliably accomplishing functions. By providing better answers, not only costs but also quality and reliability are improved.

Industrial Engineers readily appreciate the magnitude of opportunity to identify and prevent or remove unnecessary costs. Those who are able to secure training in the techniques of Value Analysis and Value Engineering will find great assistance in this set of techniques and procedures which will assist them in applying their technologies efficiently and effectively.



FUTURE DEVELOPMENTS IN DATA PROCESSING

by STAFF OF IBM

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Mr. Aeschliman graduated, magna cum laude, from Boston University, where he received his B.S. in Business Administration.

He was instructor at the Army Finance School. At IBM, prior to his present position, he was Data Processing Representative, Chicago, and later Administrative Assistant to the IBM Director of Marketing Services.

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Mr. Louden graduated from Princeton, with honors, where he received his BSME. Purdue, MSME.

He was supervisor of Engineering Data Processing at Buick (Flint) prior to joining IBM in 1960.

FUTURE DEVELOPMENTS IN DATA PROCESSING

By ROGER C. AESCHLIMAN AND ROBERT K. LOUDEN

International Business Machine Corporation

I. Introduction
   - A. Future Uses of Data Processing Equipment
   - B. Future Scope of Data Processing Systems

II. Future Uses of Data Processing Equipment
   - A. Advanced Simulation Techniques
     1. Engineering Systems
     2. Management Systems
   - B. Industrial Process Control
     1. Present Accomplishments
     2. Areas of Application
     3. Economic Factors
   - C. Other Future Computer Uses
     1. Use of Computers in Design
     2. Information Retrieval
     3. Language Translation
   - D. Future Computers
     1. STRETCH
     2. Cryongenic
     3. Thin Films
     4. Computing Speeds Obtained

III. Future Scope of Data Processing Systems
   - A. Economy of Large-Scale Computers
     1. Relative cost-power ratios of small, medium and large scale computers.
     2. Multi-programming
     3. Data Processing - "A Service Function"
   - B. Advancements in Data Communications
     1. Mercury Program
     2. North American "Microwave"
     3. AT & T and Western Union Activities
   - C. The "Information or Control File" Concept
     1. Mass Random Access
     2. Communications
     3. Operational Control
     4. Other Advantages
   - D. Advanced Systems
     1. In Plant) Electric
     2. Out Plant) Auto-Lite (Example)
     3. Saber System

IV. Summary

V. Question Period

DEVELOPMENT AND APPLICATION OF STANDARD TIME DATA

by JACK M. WAITE
Director, Work Standards
AC Spark Plug Division
GENERAL MOTORS CORPORATION

Mr. Waite is a graduate of the General Motors Institute. His practical experience covers work standards, methods, plant layout, chairman—AC Suggestion Plan Committee.

Mr. Waite is a registered professional engineer. He is a member of MSPE, AIIE and the Michigan Association of the Professions.

DEVELOPMENT AND APPLICATION OF STANDARD TIME DATA

By JACK M. WAITE

Director - Work Standards, AC Spark Plug Division
General Motors Corporation

I. INTRODUCTION

THERE has been so much written and so many talks given on this subject of Standard Data that I was, at first, skeptical of the need or interest on the part of Industrial Engineers to hear anything more. Your Program Chairman was told that we at AC had nothing new or revolutionary, nothing involving complex calculations or space age equations, nothing based on theory or assumptions -- but rather an approach developed from actual stop-watch observations recorded on spread sheets, summarized on check sheets, and used by the time study engineer to establish operation standard times.

The Program Chairman assured me that a presentation based on this approach would be of interest to the Industrial Engineers at this Convention. Of course, that was his personal opinion and you may or may not concur.

AC Spark Plug is an accessory division of General Motors supplying Spark Plugs, Instrument Panels, Air Cleaners, Fuel Pumps, Oil Filters, and some nineteen other products to industry. It is in direct competition with many highly respected and efficient companies, along with equally competent divisions within the corporation. Being a Division of General Motors does not give us a guaranteed or captive market.

While we do have many high production fabrication and assembly lines for automotive customers, we also sell to several hundred lower volume customers whose requirements vary from 25 to 25,000 a year. Our Manufacturing Departments last year produced 14,000 different part numbers in quantities from a few to many millions. The point I wish to emphasize is that, while public opinion generally regards the automotive industry synonomous with mass production, AC does have the dual problems of jobshop operation and high volume production.

Perhaps it would be best before discussing our subject to first elaborate on the term "Standard Time Data". Actually, standard time data development and application is basically an extension of the same process used to arrive at element time values on a single time study. I am sure that many of you in one way or another have used or are using standards. Long before AC activated an independent standard data group within the Work Standards Department, we used "reference" time studies whenever practical to cover similar operations. In other words, it is nothing new. Our standard data section is fifteen years old and we are still improving, revising, and refining our approach.

A separate standards group has many advantages. Standards will be more consistent. The gathering, compiling, and finalizing of recorded data is closely controlled. The check sheets or charts are designed to be uniform in appearance and presentation. The group can devote full time to downtime or work sampling studies without conflicting with a time study engineer's regular work.

A work standard calculated from standard data will be inherently consistent because it is a composite of many studies. It is impersonal because it is a composite of many operators. It allows the same element times for identical work, wherever done in the plant, making for uniformity of performance. It minimizes the need for individual operator rating because variations in operator method and output are recognized and compensated for in the analysis of elemental times.

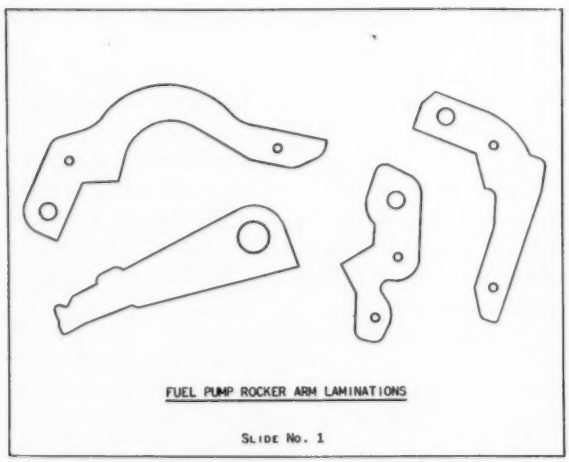
We believe the outstanding advantage of standard data is the determination of all delay elements affecting a job. An act breakdown analysis and stop-watch will readily give us the cycle time, but disagreement seldom arises over cycle time. Invariably, if a question arises, it concerns the time to get a machine going, clean chips, stockhandling inspection, tool trouble, salvage, reworking, etc. Many of these items will not be observed during a half hour to one hour study, but if studies are taken over a long period of time at all hours of the shift, then specific times can be established for all non-cycle and irregular elements.

Our discussion will cover three representative standards selected from some one hundred in current use. These hundred cover a variety of operations, such as plating, screw machines, packing, assembly operations, punch presses, cold headers, washers, heat treat, etc.

II. ROCKER ARM LAMINATION BLANKING

This first standard was developed for rocker arm lamination blanking.

Slide number one shows four of the many different sizes and shapes of fuel pump rocker arm laminations.



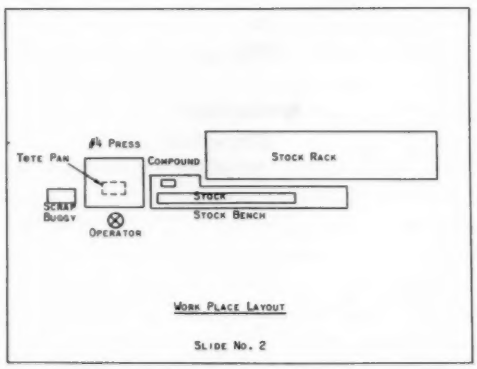
FUEL PUMP ROCKER ARM LAMINATIONS

SLIDE NO. 1

The laminations go into three piece or five piece riveted rocker arm assemblies. They are blanked on a #4 Bliss Press out of .078 strip stock eight feet long. The press is used for short run part numbers; representative schedules are 2000; 500; 1,000; 924; 300; 110. Running time for each part varies from five minutes to one hour.

Here is a situation where the same operation is performed on many similar parts. Theoretically, one standard would replace 125 individual time studies. Actually, one standard replaced a few time studies plus numerous estimates based upon those studies. I am certain this condition arises in many plants and the time study man should not be criticized. It is impossible for him to study all low production jobs when they are scheduled, so he must estimate the time from a similar part which has been studied. A standard will eliminate this estimating or guesswork. The time study analyst using the check sheet for rocker arm lamination blanking can set an accurate work standard in a few minutes.

Let's look at a sketch of the work place layout, Slide No. 2.



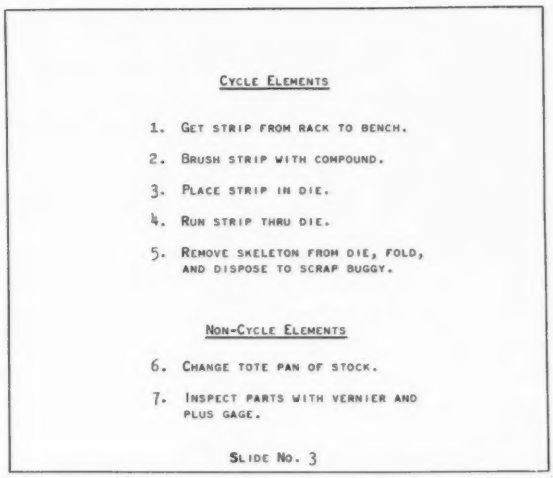
WORK PLACE LAYOUT

SLIDE NO. 2

It is a typical punch press layout with a bench on one side, a scrap buggy on the other side, a tote pan on the floor below the press, a stock rack alongside the bench. The operator gets strip stock from the rack to the bench, brushes a strip with die lubricating compound, and feeds the strip thru the die with both hands by a push-pull motion against a pin stop.

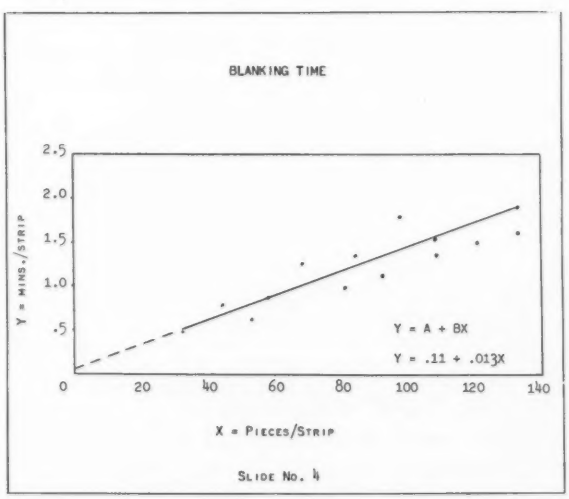
All work elements are constant except the time to feed a strip thru the die, and that varies directly with the number of pieces per strip. The work elements are separated as cycle and non-cycle as shown on Slide No. 3.

The problem, therefore, is to combine the cycle elements per strip with the non-cycle


CYCLE ELEMENTS
1. GET STRIP FROM RACK TO BENCH.
2. BRUSH STRIP WITH COMPOUND.
3. PLACE STRIP IN DIE.
4. RUN STRIP THRU DIE.
5. REMOVE SKELETON FROM DIE, FOLD, AND DISPOSE TO SCRAP BUGGY.
NON-CYCLE ELEMENTS
6. CHANGE TOTE PAN OF STOCK.
7. INSPECT PARTS WITH VERNIER AND PLUS GAGE.
SLIDE NO. 3

elements based on pieces per occurrence to arrive at a correct standard time.

Since the constant cycle elements are described and timed per strip, it is necessary to get the blanking time, a variable dependent upon pieces per strip, into the same terms. To do this, we plotted on a graph, minutes per strip against pieces per strip. The graph is duplicated on Slide No. 4. Each point represents a time study.



Some 25 time studies were taken to compile data for the standard. The studies covered a range of 33 to 133 pieces per strip.

From the plotted times, a straight line was drawn by "inspection" thru the scatter diagram to conform to the plotted points. Then, the equation for a straight line, Y = A + BX, can be developed. The terms of the equation are:

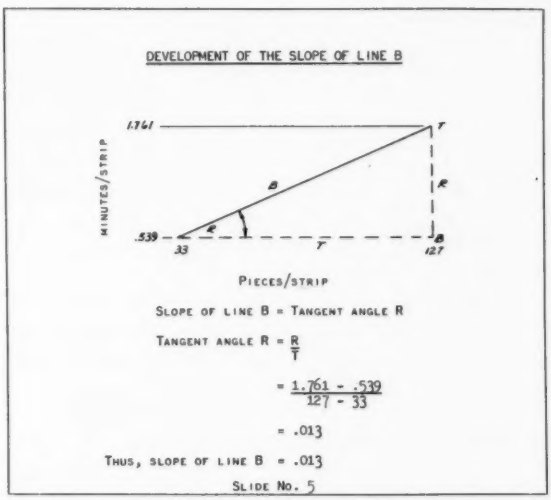
Y equals minutes per strip

X equals pieces per strip

B equals slope of the straight line, or the proportional change of time on Y axis for each change on the X axis

A equals intercept of the straight line with the Y axis

To solve for the "B", the slope of the line, let's select two points on the X axis at 33 and 127 pieces per strip and set up a triangle as illustrated on Slide No. 5.



Substituting in the original formula, Y = A + BX, we have Y = .11 + .013; or Y, blanking time in minutes per strip, equals .11 minutes plus .013 minutes times pieces per strip.

The least squares method also can be used to mathematically solve for "A" and "B", and check the slope of the line as drawn by "inspection". This method calls for solving simultaneous equations, and becomes unwieldy, requiring several intermediate computations. An alternate procedure yielding identical results by direct substitution is the calculation of the regression line equations.

To solve the "A" and "B" by the regression equations, we use the same totals as for

the least square solution: ΣX, ΣX^2, ΣY, ΣY^2, ΣXY, and N, the number of samples. Let's look at Slide No. 6.

REGRESSION LINE EQUATIONS

$Y = A + BX$

A = The Constant

B = Slope of the Straight Line

$$A = \frac{\Sigma X^2 \cdot \Sigma Y - \Sigma X \cdot \Sigma XY}{N \cdot \Sigma X^2 - (\Sigma X)^2}$$

$$B = \frac{N \cdot \Sigma XY - \Sigma X \cdot \Sigma Y}{N \cdot \Sigma X^2 - (\Sigma X)^2}$$

Slide No. 6

This line when extended met the Y axis at .11 minutes, the constant term "A". This .11 minutes occurs for every strip independent of pieces per strip, and is the time required to make two locating strokes starting the strip through the die.

The check sheet developed for this blanking operation is shown on Slide No. 7.

This check sheet exemplifies a method of combining cycle elements, constant and variable, based on strip time with non-cycle elements based on pieces per occurrence.

CHECK SHEET

ROCKER ARM LAMINATION BLANKING

Die No._____ Pcs./Strip_____ Part No._____

Cycle Elements		Std. Time per 1000 Strips
1. Get strip from rack to bench	(.093 min.)	1.55
2. Brush strip with compound	(.126 min.)	2.10
3. Place strip in die	(.105 min.)	1.75
4. Run strip thru die, push-pull against stop, single trip = 1.83 + (.217 x ____pcs./strip)		____
5. Remove skeleton, fold, and dispose to scrap buggy	(.156 min.)	2.60
	Total	____

Std. Time per 1000 Pieces

Total Std. Time/1000 Strips____ ÷ ____Pcs./Strip ____

Cycle Production_____

Non-Cycle Elements

A. Change tote pan of stock 1.75 mins./1560 pcs.	.019
B. Inspect parts with verniers and plug gage .85 mins./1150 pcs.	.012
Sub-Total	____
C. Personal 5.26%	____
Total Std. Time	____

Date_____ Calculated by_____ Foreman_____

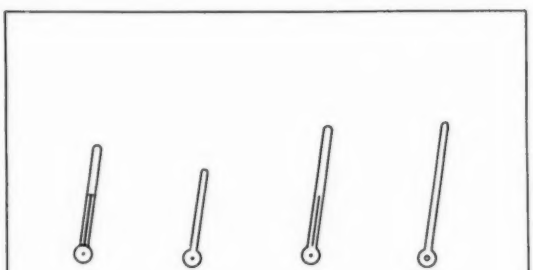
Slide No. 7

III. GAGE POINTER BLANKING

On the check sheet just discussed, we kept the cycle elements in terms of minutes per strip to compute cycle time, then added the non-cycle stock-handling and inspection elements in standard time computed by frequency of occurrence. Now, let's look at another standard for the blanking operation of gage pointers. Slide No. 8 gives an idea of the size and shape of four different pointers.

They are blanked on a Stiles Press from aluminum strips 22 inches long. All strips are etched and spray painted before blanking, and 22 inch strips are most economically handled in the etching tank and spray booth. Some 200 part numbers are run on this press.

The cycle elements are directly related to pieces per strip and are computed the same as for the rocker arm lamination standard. However, certain work elements occur, not dependent upon pieces per strip or pieces per occurrence, but requiring a specific amount of time each shift.



GAGE POINTERS

Slide No. 8

These elements are:

1. Clean up work area during changeovers
2. Get inspection OK on new part after changeover

3. Write up inspection and OK tag for stock at end of run
4. Oil die four times per day
5. Visual inspect and sort stock
6. Personal time

They totaled 45.30 minutes per day. Now, to the cycle time in minutes per piece must be added the six delay elements in minutes per shift. To add these unlike factors, minutes per piece and minutes per shift both have converted to standard time. The conversion is shown on Slide No. 9.

STANDARD TIME COMPUTATION

480 MINS./SHIFT - 45.30 MIN. DELAY = 434.70 MINS. AVAILABLE.

434.70 MINS. AVAILABLE ÷ _____ CYCLE MINS./PC. = _____ PCS./SHIFT

DELAY ELEMENTS

	MINS./DAY	÷ PCS/SHIFT	÷ .06 =	STD. TIME/1000 PCS.
A. CHANGEOVER	12.10	÷ _____	÷ .06 =	_____
B. REJECTS & OIL DIE	9.20	÷ _____	÷ .06 =	_____
C. PERSONAL	24.00	÷ _____	÷ .06 =	_____

CYCLE TIME

_____ CYCLE MINS./PC. ÷ .06 = _____

TOTAL STD. TIME _____

SLIDE NO. 9

Thus, development of check sheets for the rocker arm lamination standard and the gage pointer standard presented a different approach and solution to essentially the same type of operation.

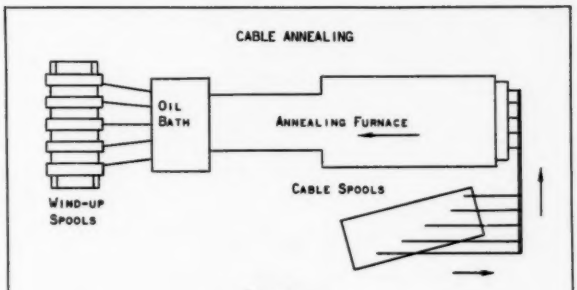
IV. CABLE ANNEALING

The two standards previously discussed require the use of a check sheet to compute a work standard.

Occasionally, an operation involving several hundred part numbers can be set up so that the standard hour payment becomes a constant multiplied by a known variable of the part. An example is the annealing of cable for flexible shafts. Some 450 part numbers are covered.

The layout is seen on Slide No. 10.

The five cables run continuously. The first shift operator starts work one-half hour early to have cable available for the cutoff operation.



LAYOUT

SLIDE NO. 10

The furnace is not shut down between shifts. Since the operator does not run all five spools on the second shift, a capacity loss occurs.

Knowing the feed rate, we can easily compute standard time by changing feet per minute to minutes per inch and then to standard time per 1000 (1'') lengths. To the computed cycle is added the time for loading the furnace in the morning, unloading at night, and capacity loss of two shift operation.

The calculated daily footage is 107,100 feet. The cycle time is .0132 hours per 1000 (1'') lengths. To express the non-cycle elements in standard time, we first determine the footage loss for these items. The starting losses are listed on Slide No. 11.

STARTING LOSS

STARTING ORDER	SPOOL NO.	MINUTES/SPOOL
1	2	9.80
2	3	16.80
3	1	24.25
4	4	37.40
5	5	44.60
	TOTAL	132.85

132.85 MINUTES X 21 FT./MIN. = 2790 FEET STARTING LOSS.

SLIDE NO. 11

The end of shift loss is 1,181 feet, and the capacity loss is 12,206 feet, making a total loss of 16,177 feet. Changing these footage losses to percentages of cycle time, we arrive at one standard time constant. The computations are shown on Slide No. 12.

Thus, the payment for annealing a 60 inch

CABLE ANNEALING

STANDARD TIME COMPUTATION

CYCLE ELEMENT		STANDARD TIME PER 1000 (1") LENGTHS
MACHINE CAPACITY (105 FEET/MINUTE) - - - - - - - - - -		.0132
NON-CYCLE ELEMENTS		
A. START & FINISH LOSS	$\frac{3,971}{107,100 - 16,177} = 4.37\% - -$	.0006
B. CAPACITY LOSS	$\frac{12,206}{107,100 - 16,177} = 13.42\% - -$	.0018
	TOTAL - -	.0156

STANDARD TIME CONSTANT .0156 HOURS/1000 (1") LENGTHS

SLIDE NO. 12

cable would be .0156 times 60 inches equals .936 hours per 1000 (60 inch) cables.

This standard demonstrates a problem in developing a single constant for standard time payment. It illustrates the necessity of compromise when job conditions make it impossible to standardize method and procedure. Actually, the standard is not correct for first shift or second shift only, but it is correct for the overall two shift operation.

CONCLUSION

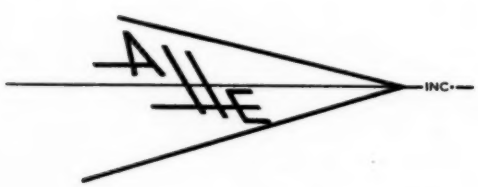
We have discussed the development and application of three standards used at AC. The plant you represent may not fabricate fuel pump rocker arm laminations, gage pointers, and cables, but the approach and solution to standard data, as demonstrated by these three standards, is fundamentally sound and universally applicable.

The development of standards does not require a specialist or so-called expert because any time study man can develop standard data. It is, as stated earlier, an extension of the same process as used to arrive at element values on a single study. The problems encountered are no different than you find in time study. Standard data gives you the answers to those problems by a systematic approach to the compilation and evaluation of accumulated data.

AC's utilization of standard data through a separate section within the Work Standards Department, definitely improves the effectiveness of the department. If a time study analyst can set a standard for cable annealing by multiplying cable length times a constant, or can set a standard for rocker arm lamination blanking in a very few minutes; then his effectiveness has been substantially increased.

Standards are not necessarily limited to high production, repetitive operations. Regardless of product manufactured or quantities scheduled, standard data can be used successfully.

We are convinced that the use of standard time data does pay big dividends.



CAPITAL COST - PLANNING CONTROL

by HARTWELL G. HOWE
Vice President and General Manager
THE HEALD MACHINE COMPANY

Mr. Howe first joined the Heald Machine Company in 1939. He has been concerned primarily with the Sales Organization having been head of the Sales Proposal Department and more recently sales manager of the company. His present position is executive vice president and general manager. He is also a director of the organization.

A graduate of Northeastern University, he holds the degree of Master of Science, Mechanical Engineering.

CAPITAL COST - PLANNING CONTROL

By HARTWELL G. HOWE

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INTRODUCTION I

FIRST of all let's begin by defining terms. It's always best to make sure we all are talking about the same thing. I plan to discuss with you the concept of cost - capital cost - control as a form of long range planning. To do this I quite naturally have chosen the case history method. The facts and figures are those as taken in the abstract from our own experience along these lines. Again this was a natural not only because I am more familiar with the subject matter but also because I feel that our own situation at The Heald Machine Company may have universal appeal and interest to this audience in terms of size, available funds and general business conditions.

You should next know who we are (Heald) and what we do. Heald is a machine tool manufacturer, neither very small nor surely not very large being in normal times, whatever they may be, a group of some 2,000 employees. The main plant, established in Worcester, Massachusetts some 58 years ago, consists of several groups of modern or modernized manufacturing and office facilities representing a series of different expansion programs over the years

As a further frame of reference the individual unit (machine) selling price averages $30,000 in today's market and in some cases annual unit shipment volume can run into 4 figures.

Our product enjoys acceptance with automotive, anti-friction bearing, aviation, home appliance and power tool manufacturers - indeed pretty well throughout all metalworking industry where metal removal is a requisite. However, we are heavily dependent on the automotive and anti-friction bearing manufacturers for nearly 50% of our business. It has been truly said - when Detroit sneezes the machine tool manufacturer catches pneumonia.

At present writing the machine tool industry in this country is experiencing an abnormal imbalance of export sales to domestic; Exports running unusually high percentage-wise.

So much for a background - I tried not to make it sound too much like a commercial.

REAL ESTATE II

Let's look at the first category then of capital cost - and the planning that can help control it. We speak first then about Real Estate and its associated elements - buildings, power and heat source, air conditioning, security items such as gates, fences, radar, etc.

A year or so ago "Factory" magazine published an article entitled "Master Planning Modernization" which featured the Heald story of its long range planning. As is evident by the aerial view illustration Heald appears to have "grown like Topsy". Such is not exactly the case since Topsy apparently progressed without much of a plan or strategy.

We established what might be called the Three Year Look-Ahead. This may be described as follows to quote briefly from the article appearing in Factory magazine:

"THREE YEAR LOOK-AHEAD"

Each year Heald prepares a capital expense budget covering a three year period as well as its regular yearly budget. As our Works Manager says, "We can't accomplish the short-range plan without making a long-range plan." Three years may not sound very long range, but it comes to budgeting on manufacturing and

Figure 1

maintenance, five years is too far out, three years is just right. Heald knows. We tried the five-year plan, but without success.

The Company does look much further ahead than three years, although the really long-range planning is more difficult in terms of dollars and cents. But the three-year budget is a fairly firm schedule of capital expenditure for plant modernization. It goes to the Board of Directors for review. But even their review doesn't change the year-to-year basis of appropriations that are determined by the annual budget.

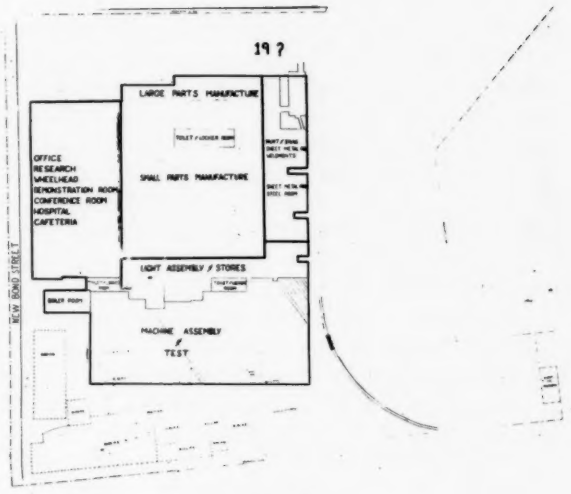
The three-year budget is especially useful for slotting the projects that should be undertaken but (for one reason or another) cannot be done in the year immediately ahead. Without a plan such as Heald's these projects are sometimes tabled and forgotten. With a look-ahead budget there's a place of recognition for these ideas - a place where they won't be lost.

True, the overall three-year budget tends to get pretty heavy in terms of money required. But many future projects can be postponed longer or cheapened when they're considered for the next-year budget. On the other hand, the cost of staying modern may appear high but it *has* to be faced and dealt with. Limiting capital budget proposals to anything less than adequate is sure to result in "rundown heels" before the passing of many years. And that's what Heald is trying to avoid.

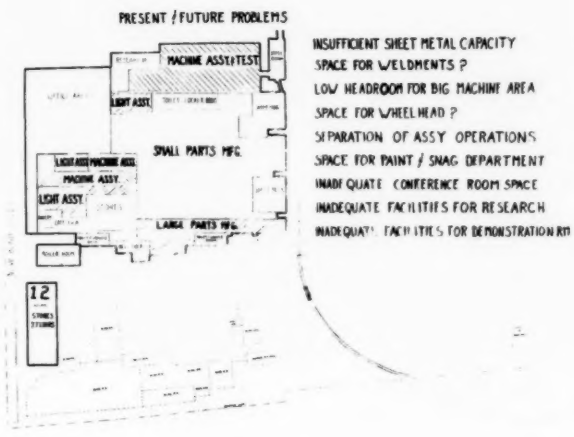
The three-year budget carries with it a look-ahead at broad needs as well as individual

pieces of equipment. A case in point is the boiler house built in 1940. At the time the demand for power was only a fraction of what it is today, but Heald went ahead and built a new power house big enough to accommodate new equipment until mid-1957."

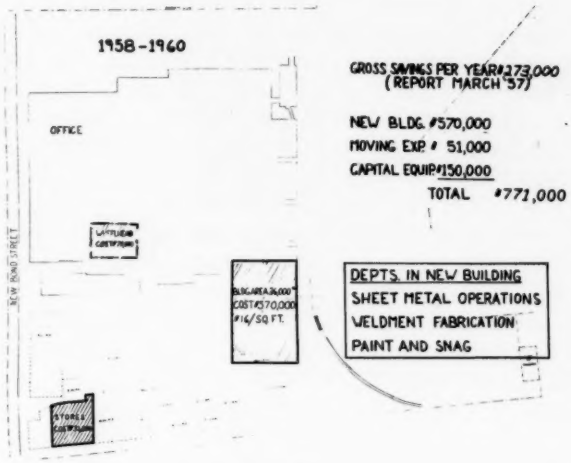
Briefly, to decide on capital expenditures for buildings and associated plant facilities during any projected three-year period we must consider our overall needs, possible long-range solution of these needs, short-range financial position and forecasted sales for the same projected period. It goes without saying that immediately anticipated projects must fit into the long-range plan in such a way that they don't forestall or prevent the accomplishment of longer period planning merely for the sake of satisfying an immediate need. For instance (Maps 1, 2, & 3).



Map #2



Map #1



Map #3

DIRECT COSTS III.

The second category of capital cost and control is in the area of manufacturing equipment i.e. machine tools and other such items as are more directly concerned with the manufacture of our product. Biggest and most important element is that of machine tools - for the manufacturer of machine tools depends heavily on other machine tools to reproduce themselves. Foundry equipment is not considered in this particular discussion since we go to outside suppliers for castings and basic metal, it very well could be another major portion of consideration in another study.

Heald keeps an up-to-date record of average ages of all categories of production equipment. In a bar chart (show chart) each bar shows the current age of each piece of equipment according to type - lathes, millers, grinders, drills and so on. On each bar is a line representing the ideal age of equipment in that particular category - that's the goal we shoot for.

Each year every bar moves up one full notch unless some equipment is replaced - as our Works Manager points out "Machines as a group tend to grow old in a hurry unless we are constantly replacing the older ones."

Equipment age is a workable indicator of a

plant's ability to compete in price and quality. But it is not the sole criterion. We apply a modified Heald MAPI formula to our own machine tools, too (as well as to those of our customers in hopes of selling in the replacement market). This helps to determine which specific machines should be selected for replacement - and when. The formula is also a means of comparing new machines with new features against the machines now in the shop regardless of their age.

Age of itself is not synonymous with obsolescence - yet it is a likely indicator. In the relatively new precision instrument industry, 45% of the machine tools are over ten years old and in the aircraft industry 49% are over this age. In other industries more than 60% are past the ten year mark. You may consider a ten-year prime productive life as a bit short. But even on a one shift, no overtime basis in ten years a machine tool will have operated eight times as many work hours as an average automobile in its entire lifetime. A lot of precision and production has been taken out of the machine tool in those ten years. Furthermore, the pace of technological progress and improvement puts a ten year old machine at a 30 - 40% productivity disadvantage in many cases.

Production managers know that machine tools have given up the best years of their lives by age ten but financial executives have been thinking in terms of accounting practice - and so has the Bureau of Internal Revenue with its 18 - 25 year useful life concept.

Consequently, appropriations are sometimes hard to come by. However, if we expect our customers to replace old equipment our planning and capital cost control should practice what it preaches. That it has to some degree accomplished this end is evidenced by the fact that we have recently purchased three large machine units, each of which run well into the six figure category - and this despite the lack luster tone of business activity in our direction.

INDIRECT COSTS IV.

The third item concerns itself primarily with capital costs which are not directly connected with the actual manufacture or fabrication of our product. Such items might include automobile and truck fleet, office and duplicating equipment, fire fighting and snow removal machinery or vehicles, bookkeeping machine, typewriters, etc. This category covers a wide variety of items and by its very dissimilarity complicates the process of evaluation. Replacement formulae can indeed often be used to advantage but each case may differ. For instance, in the requisition of bookkeeping machines a decision must be reached as to the feasibility of renting as opposed to purchasing the equipment. The same would be true of the fleet of trucks or cars - the reasonable break even point by a variety of methods must be known. If renting as opposed to purchase seems best, then there can be no capital cost involved - the items are expensed out.

Supervisory personnel in various departments must be relied on heavily to advise top management of replacement and modernization needs. The Cafeteria Manager for example is best qualified almost to exclusion of all others to determine his feeding problems - this can change drastically almost overnight in the event of an increase in work force.

Legislation effecting safety practices can immediately outdate fire fighting equipment necessitating purchase of additional or new equipment.

Even more so that in the case of production equipment which is more generally under continual scrutiny, the continued evaluation of indirect capital costs must be left to specialists. The Cafeteria Manager, the Safety Engineer, the Business Machine Supervisor must be relied on to advise those in charge of capital costs of ways and means to operate more efficiently. This should be done in both good times and poor.

It is not up to middle management group to make the final decision but it is their duty to keep top management informed regardless of whether they (middle management) feel that the item recommended can be bought at the time.

CONCLUSION V.

No discussion of the problem of cost and capital expenditure would be in any way complete without touching on the subject of modernization in general. The editors of industrial magazines have waxed eloquent on the subject for some time. Burnham Finney in

particular Editor of American Machinist magazine has this to say in an editorial entitled "Before it is too late" and dated February 6, 1961.

"Never has the physical condition of our nation's industrial plant been worse than it is today.

What's more, the machinery is getting older, more obsolete, less efficient and more costly to operate year by year. And unfortunately not enough money is being spent on new equipment to reverse this disastrous trend.

This neglect . . . of our industrial machinery is one of the reasons that we are in a recession.

Nothing is more important to restore our economy to full vigor than to remedy this dangerous situation by encouraging investment in new equipment. Such investment has sadly lagged for too long.

The new administration in Washington, fortunately, is apparently taking steps to alleviate the problem. With its New Frontiers approach, it already has brought into prominence a new term and a new plan that should help to solve the problem promptly. I refer to the "investment credit" plan.

This plan specifies that a manufacturer can deduct from his final tax bill a percentage of the amount by which his investment in new plant and equipment exceeds his depreciation deduction during the year.

One of the great merits . . . of this plan is simplicity. The plan also is highly flexible, because the percentage of allowable credit can be raised or lowered or even removed as conditions warrant. More than that, it does not require any change in tax accounting of depreciable assets already on a manufacturer's books.

Another simple way to stimulate capital spending is to increase sharply the tax depreciation allowable the first year. Other industrial nations have resorted to this device with eminent success. The United Kingdom and Japan have permitted writeoffs of more than 50% the first year. In Italy and Sweden it is over 30%. Yet in this country it is a miserly 13%.

It would be idle to pretend that either the "investment credit" plan or a big stepup in the initial writeoff is the ideal way in which to induce industry to expand and modernize its plants on a continuing basis. But it would be a constructive and stimulating start in the right direction.

Before our industrial plant . . . deteriorates further to a shockingly poor level, there just is not time for long, exhaustive studies of depreciation. Congress therefore should enact into law at the earliest practical time either the "investment credit" plan or a sharp increase in allowable first-year depreciation rates.

But the Government should not stop there. It should begin work immediately on a sweeping revision of the rules and regulations governing depreciation of capital goods. For the long-term pull, such revision is a sound and permanent solution of the problem of keeping our industrial plant modern by encouraging the use of new technological advancements now available."

Each of us is, of course, concerned with our own particular problems - our capital cost control efforts cannot be geared primarily to the future of the country at large. Yet, if we are to be entrusted with capital cost control as individuals we can hardly be unmindful of the national and international implications involved.

What can we do, you may ask. Isn't ours a still small voice in the wilderness as management people? How can we expect to communicate through our employees for instance that they should be heard? This is too much to ask.

Recently I attended a session of the National Chamber of Commerce's Aircade. Many present asked questions similar to the foregoing. The answer came loud and clear. Too long has management in the person of those present here today neglected to sit down and express themselves to Government representatives in quantity of numbers as to the stand they take. Too long have they felt that communication at the employee level is the only answer. Mass communication can help to be sure, but middle and top management must not let it drop there - they should take the active lead.

This is good advice - as Burnham Finney says "Before it is too late".

INDUSTRIAL ENGINEERING MANAGEMENT SYMPOSIUM

GERALD E. CLARK
Chairman

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Mr. Clark spent two years with I.C.A. in Brazil, establishing a new school of business administration and installing an industrial engineering curriculum in the University of Sao Paulo.

INVITED TECHNICAL PAPERS

THE SIMULATION OF A PRODUCTION LINE*

An Engineering Approach to Studying a Complex Problem

By HARRY SCHREIBER, JR.

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THE INDUSTRIAL Engineer is often presented with a product which is to be made by a certain series of operations. He is asked to design a production system which will make the product. Immediately, there are a number of basic problems; these range from the broad decision of whether or not to manufacture it on a line, to the precise layout of individual work places. There are factors which should influence his decisions, certainly volume is one, but to make a rational decision he must know all of the factors that are relevant and how they interrelate.

Most research in this area has consisted of studies of certain "relevant" factors. They have been studied independently, without relative values being placed upon their effect on the total job. These factors do, however, combine to form the system which is the job. This immediately suggests an integrated model. In order to appraise a model or test different assumptions, one must try out the model. Simulation on a digital computer is an economical and useful way to "operate" the production line. This paper describes the construction of a generalized computer model of a production line, and discusses the application of data from a specific production line to this model.

PRESENT INDUSTRIAL APPROACHES

Various engineers think that the controlling factor is one or more of the following: desired output, available space, available equipment, job content, line length, learning, turnover, absenteeism, aptitude of workers, capital cost, or supervision. Very often an engineer will subscribe to two or three of these as the controlling ones and design his line accordingly.

One of the more common procedures is to determine probable total labor content. This is divided into the daily working period to get output per individual. Daily output per individual is then divided into the desired daily output to determine the approximate length of the line. The job is then balanced for a line of that length. This is the procedure that is assumed in most of the recent papers on line balancing (5, 6, 9, 10). The best thing that can be said for this method is that it does give a definite solution. It can not tell you that the most efficient way is to have a large number of people all doing the *complete* operation; neither can it tell you that a better way might be to have a line twice as long and run it only half the time.

Another, perhaps rational, way to determine line length and configuration is to determine space available; then to design a line within the area. Other lines are designed in such a way as to minimize capital cost or to utilize existing equipment.

These decisions, then, are usually based either upon someone's experience or upon happenstance. Seldom are they founded upon logical appraisal of the relevant factors. "Experience" is often suspect, and we have considerable evidence that such experience is seldom uniform or unbiased (4). There exists considerable disagreement as to what factors are important. The basis for decision in one company would not even be considered in

*The research described in this paper was performed in the MIT Management Laboratory. It was supported by a grant from the Sloan Research Fund of the School of Industrial Management of MIT and the computational work was done on the IBM 709 Computer in the Computation Center of MIT, Cambridge, Massachusetts.

another, comparable, company.[1]

There are psychological factors such as motivation and satisfaction which are not what might be referred to as "mechanical" features of the work situation. It is the author's feeling that these may be of critical importance. The present model does not compensate for them; it does make provision for adding them later. Since we do not know the true effects of these factors, it should be interesting to experiment with various assumptions about the mechanisms by which they effect productivity. With a simulation model it is possible to try out such assumptions and look at their effect.

PREVIOUS WORK

The bulk of the writing in the field can be characterized as "Wisdom Literature." ("It should be done this way!" "From my experience", etc. - in other words, opinion which at best had probably only been tested a few times under uncontrolled circumstances.) This is not a good guide for the engineer, but it can be a fruitful source for the experimenter in search of possible hypotheses. There has been some useful work on the problem in general and on some of the details of the problem.

A number of articles have been written about "Job" or "Work" design. Rather than suggesting how jobs should be designed, they have more generally either exorted us to do job design or job design research. The articles usually discuss some of the ideas noted in the introduction to this paper. If they have any recommendations about doing job design, they suggest that some of the more basic tools of work simplification be used before the job actually begins. I am sure that this is part of the answer; I suggest that we must investigate how the important factors interrelate before we decide *what* to optimize.

The experimental psychologists and the human engineers have made careful studies of such factors as learning and variations in aptitude among individuals. These studies tell us much about the behavior of certain factors under differing conditions. It is now necessary to ascertain how variations in these factors influence overall productivity.

PREVIOUS WORK AT MIT

Because of interest in this area, a research project was initiated at MIT in 1955. A project team composed of Professors Herbert F. Goodwin and Leo B. Moore of the Management Laboratory of the School of Industrial Management, and Dr. Herbert Galliher of the Operations Research Center experimented with various methods of studying the production line system.

AN ANALYTICAL SOLUTION?

Their first approach was an attempt to develop an analytical solution to the problem of line length. There were two immediate difficulties: (1) the facts available upon which to base any equations, and (2) the number and complexity of the non-linear equations which would be required to produce an analytical solution.

EXPERIMENT WITH AN ACTUAL LINE

One possible source of data would have been to actually experiment with a line in industry. There were enough companies willing to be studied, but no company could promise that the economic requirements of a competitive business would not interrupt or distort any work which the researchers might do. There would also have been considerable cost involved in changing actual line configurations, and in training workers on new jobs. The psychological problems of studying people (e.g., the Hawthorne effect) remained unsolved in such a procedure.

SIMULATION IN THE LABORATORY

For a combination of these reasons it was

1. In one particular industry where the end product was substantially the same, a review of procedures in several different plants revealed wide variations. The "set-up" used at each plant was vociferously defended as the best possible, yet no data could be uncovered to substantiate the claim or that a study had been made upon which to base the decision. Most methods had been "sold" or "installed" under the guidance of someone who had had "years of experience" in the field or had a specialized piece of equipment to sell (3).

decided that a controlled simulation was the best alternative. Digital computer simulation techniques were not available at that time, so their procedure was to simulate a line with real workers in a laboratory situation. They devised a job - the assembly of numerous odd parts to a plastic tray. This job was broken down and balanced for lines of from one to ten people. The line was then operated in all ten configurations, using paid MIT students as workers. Two graduate students functioned as management. This experiment did not produce any conclusive evidence about the nature of production processes. The variations were more attributable to the facts that these were MIT students, that this was not a real product, that the students sometimes competed on output, and that the line was constantly the subject of observation. In addition, they were not, for practical economic reasons, able to run the line for a long enough period in any given configuration.

THE MODEL
CRITERIA FOR THE PRODUCTION LINE MODEL

The first objective of the present research project, which was started in the Spring of 1960, was to build a simulation model of a production line that would meet certain broad criteria:

1. The line must process products piece by piece, with individual workers doing their separate operations on each piece.
2. The individual workers must have a cross-section of normal characteristics; they must be absent, quit, learn, have variable cycle times, and make mistakes. The original model should include all factors which might reasonably be construed to have some effect. Factors whose effect turned out to be negligible can later be dropped from the model.
3. The model must describe the interrelation of physical features and constraints upon the line. For example, line must not be perfectly balanced, it must be of a given length, it must sometimes stop because of mechanical difficulty, etc.
4. The model should be a general one, it should be possible to introduce the parameters and decision rules of any specific line. If we are really developing generalizations, they should hold for more than one line and more than one industry.
5. A test of the model with real data from a production situation should produce production statistics which *resemble* those from the same production statistics, because of random variations in both the model and the actual line. The output from the model should look as if it could reasonably have come from the existing line. If the model is built up completely from the relationships and the data and it yields the same output as the real line, it can be considered a *reasonable* model.

FACTORS IN THE MODEL

The next problem is selecting the factors which should be included as a part of the model. These include the physical characteristics of the line, the characteristics of workers that are relevant to line operation, and some factors such as scrap which may be partially inherent in the job and partly due to the worker. The following factors are currently considered in the model:

Line Length or Cycle Time - These two factors are directly related. Given a total labor content, if you specify a line length, you automatically specify an approximate cycle time, and vice versa. By line length we specify the number of stations in the line. The time required for the worker in the line with the longest job is the cycle time.

Size or Existence of a Float, Bank, or Backlog - This is the number of pieces piled up after one operation and waiting for the next. A large "float" allows for wide variations in individual cycle times between operators without necessarily effecting immediate production.

Balance - The manufacture of a part is usually composed of a number of small, finite, and indivisible operations. For this reason, when we manufacture a product on a line, we cannot simply divide total labor content by line length to get all equal cycle times. If we could do this, the line would be perfectly balanced. Since we must add up small, incremental operations (which very often must take place in some rough sequence), the line is generally out of balance. The shorter the cycle time,

the harder it is, in general, to achieve balance, and more time is lost because of the "out of balance" condition.

Downtime - There is a certain probability that the line will cease operation for a period of time because of some mechanical equipment failure or because of lack of necessary supplies.

Variability in Cycle Time - The worker will have a certain distribution of cycle times, the mean of which is what is generally referred to as the cycle time. These variations may be due either to variations in the inherent characteristics of the material and the process or in the normal variations in the operator's own speed. A typical distribution is illustrated in Figure 1; note that the distribution is skewed

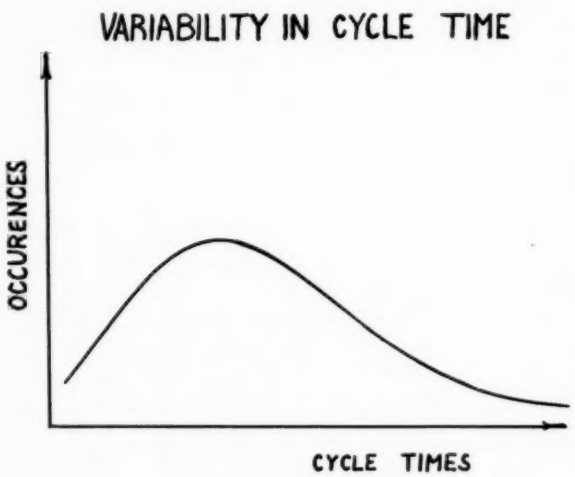

Fig. 1.

to the right. It may be possible to take twice as long to do the job, but the reverse is not the case.

Scrap - There is a certain probability of producing bad products, or scrap. Again this is partly a function of the operator. There is reasonably good evidence that the operator controlled scrap is inversely proportional to the learning and perhaps the attitude of the operator.

Learning - It takes a new worker a certain length of time to learn a job. There has been considerable investigation of industrial learning curves, and they generally follow the shape of the curve in Figure 2. This is a natural

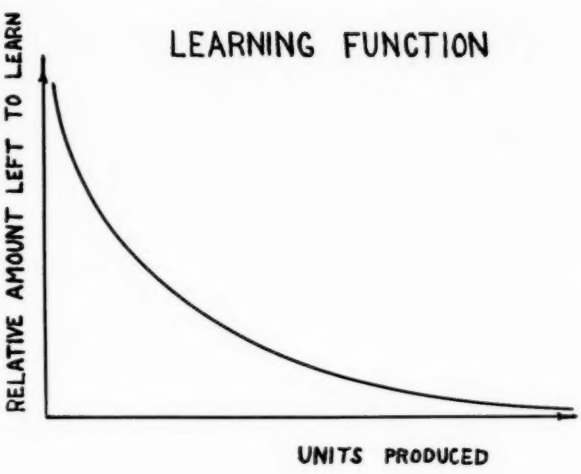

Fig. 2

decay function which approaches a "normal" cycle time as a limit.

Absenteeism - When a worker is absent, one must either stop the line, or run the line with a substitute worker. If the latter is done, the substitute may not have completely learned the job, so that production is slowed down to the speed of the learner. An expensive alternative is to have available trained "utility" workers who are expert in all jobs.

Turnover - When one loses a trained worker, he must hire someone, usually one who is not trained for the job. This will slow down production, even if a partially trained (from absences or training) worker is available. In industries where employment is predominantly female, turnover rates often approach 100 per cent per year. In such a situation, turnover is usually considered a most important item.

Aptitude of Workers - Some workers are naturally capable of doing a more efficient job on a given process. Testing and selection procedures can help to reduce variations in aptitude, but they cannot eliminate it.

Time of Day Efficiency - The average job speed actually varies during the day. We recognize that the worker would usually produce more at nine o'clock in the morning than at four in the afternoon.

Worker Pool - These are workers, not actually on the line, who are available for use on the line in the event of an absence or a quit.

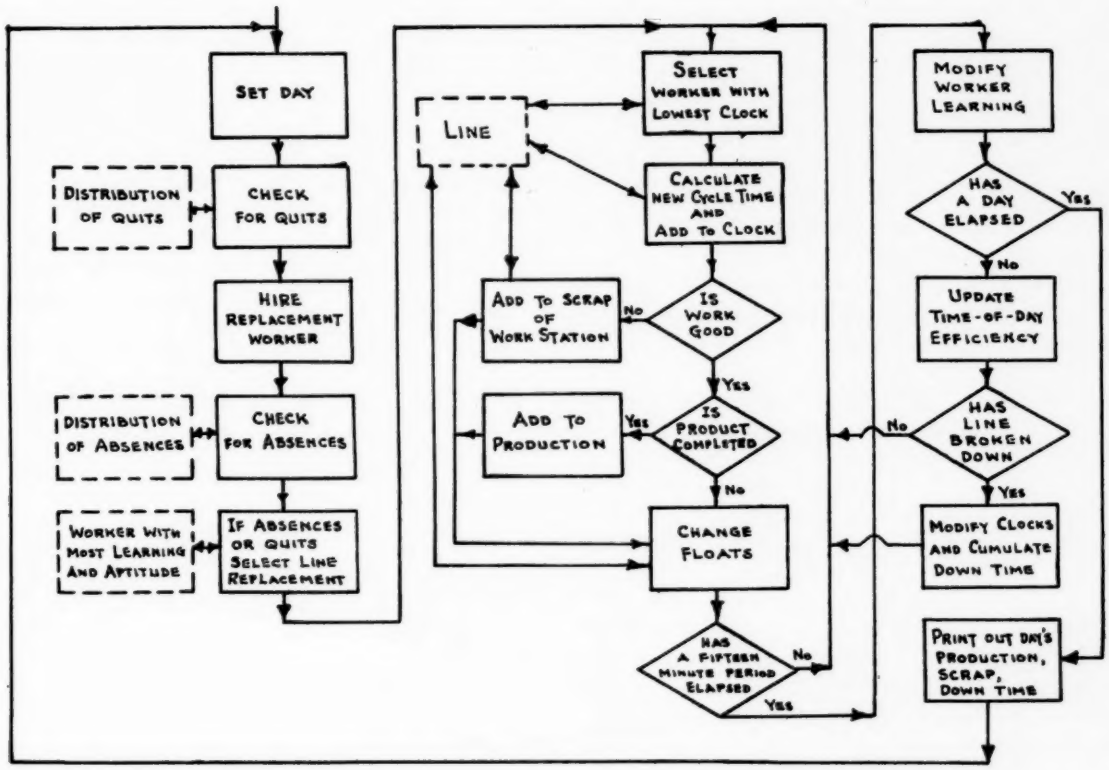

Fig. 3

THE OPERATION OF THE MODEL

To construct a model, it was necessary to interrelate all of these factors. After talks with numerous production managers, industrial engineers, and management analysts, a very detailed flow chart was developed for the decisions and occurences which govern the operation of a production line. A condensed summary of this flow chart is shown in Figure 3. Our model can be broken down into three main segments: 1) those occurences which can be construed as happening only daily, such as absences and quits, 2) those happenings and decisions which occur cycle-by-cycle on the line, and 3) those cycle-by-cycle occurences which we choose to deal with at fifteen minute intervals in order to save computer time.

The actual operation of the line starts at the beginning of the day when we check each worker to see if anyone has quit or is absent. The probability of a person quitting is expressed as a fraction of one, and this is our criterion value for quits. A random number is then generated, also a fraction of one, and if it is less than the criterion value, the worker has quit. Absences and the duration of absences are also determined in this manner.

If someone quit, it is necessary to hire another worker. Currently the computer "hires" a worker from a group of workers which have been supplied to it. However, a computer subroutine has been written which, if given certain broad population characteristics, will generate a typical worker with the necessary initial characteristics. Since it is not often possible to hire a new worker and put him to work effectively on the same day that a worker quit, there is a hire delay. This does not allow the model to use the new hire for a certain period.

In the case of either a quit or an absence, it is necessary to select a worker for the open station in the line. The method of this selection varies between companies. It is one of the decision rules which, we anticipate, will

be modified with each line situation that we "model".

With a worker in each job, the line is prepared to operate. This operation is best illustrated by referring to Figure 4. The first view shows the line at the beginning of the day. Each worker is shown in position. Each has a "float", and a clock which shows the time at which he will finish the piece upon which he is working.

The first step is to compute an initial cycle time for each worker. All cycle times are computed by the following formula:

Actual Cycle Time = operating cycle time + (handling cycle time) X (job speed factor) X (aptitude factor) X (learning factor) X (time of day efficiency factor)

Operating cycle time is the machine paced time that does not vary. The job speed factor is selected at random from times in the job speed distribution. The other factors were discussed previously.

After cycle times are computed for each worker (view 2), the computer goes through the line and selects the man with the minimum clock; he will be the first worker to start on his second piece (view 3). The computer therefore computes a cycle time for his second piece. It adds this time to the workers clocks, adjusts the workers floats (or production if this is the last worker) (view 4), and then goes back and selects a new minimum clock (view 5). The sequence continues as a new cycle time is computed for the worker with the minimum clock. The sequence of operation follows throughout the day.

Every fifteen minutes of simulated time the computer interrupts his sequence to make certain tests and modifications. These should be going on continuously during the day, but the effect of a change on any given operation is relatively negligible. For this reason, and to conserve computer time, these calculations are taken out of normal sequence and are performed only at these intervals. The worker is of course learning continuously; but his learning factor is adjusted on the learning curve for every fifteen minutes that he works. There

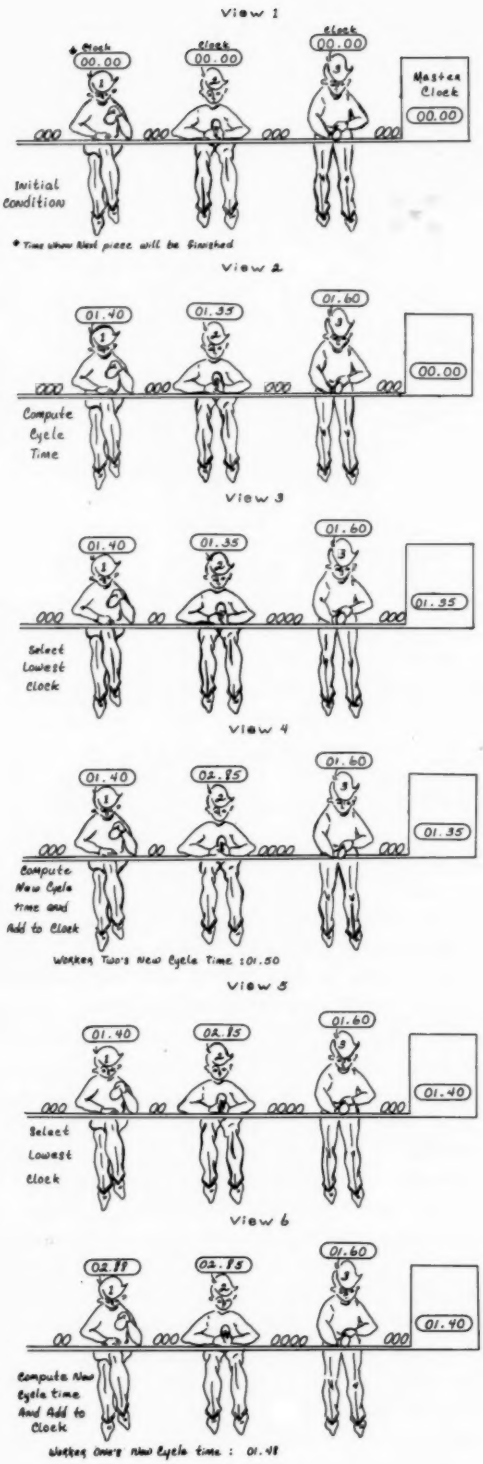

Fig. 4

must be a check to see if a day has elapsed, and, if it has, the computer prints out production statistics for the day, and resets everything to begin a new day. If a day has not been completed, the time of day efficiency factor is updated for the next fifteen minutes, and the line is checked for mechanical failure or downtime (by use of criterion values and random numbers). If the line is down, the computer determines how long it was down and updates the worker's clocks accordingly. The computer then goes back to the line and operates.

THE ELECTRICAL APPLIANCE COMPANY

The First Test Case

The previously defined test of the model is to insert the decision rules and data from a real line in an actual company, and see if the production statistics appear to be from the same line.

In selecting a production line to simulate, we looked for one whose operations might be considered "general" operations. We did not want operations peculiar to a specific industry or company. The desire was to simulate a line which could be located anywhere in the country, in any of a number of industries. We required the line to have been in operation long enough to have a history, and that the skills in the line not vary greatly.

After some preliminary work, a manufacturer of electrical appliances was selected as the first subject company. The company had good time study data and had adequate records of most of the factors of interest. Conferences with the production management and observation of the line established the decisions rules such as priority of assignment of workers to the line and line discipline. Line length and size of floats were immediately available from observation and layout drawings of the line. Current state of balance was available from time studies (in fact, element times were useful in balancing lines at other line lengths). The actual time study readings were used to establish the variability of the cycle time. Downtime, scrap, absentee and turnover distributions were readily available from company records. The company had reasonable learning estimates from which it was possible to project a learning function. There was no immediate record of aptitude, so this factor was set to one for the initial runs. The company had not measured their own time-of-day efficiency but believed that it conformed with industry data, and therefore, the industry data was used as a first approximation.

The decision rules and the data were entered into the computer model, and the model was tested to establish the fact that it was performing as planned.

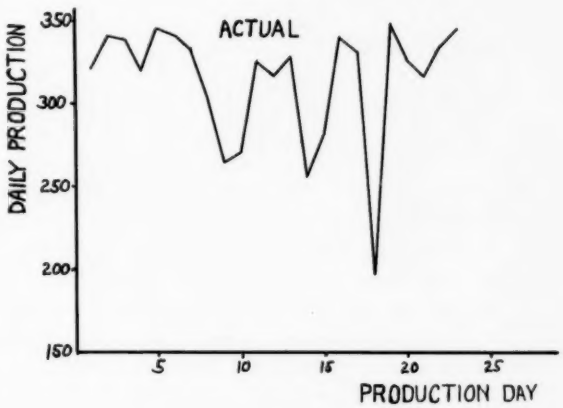

Fig. 5

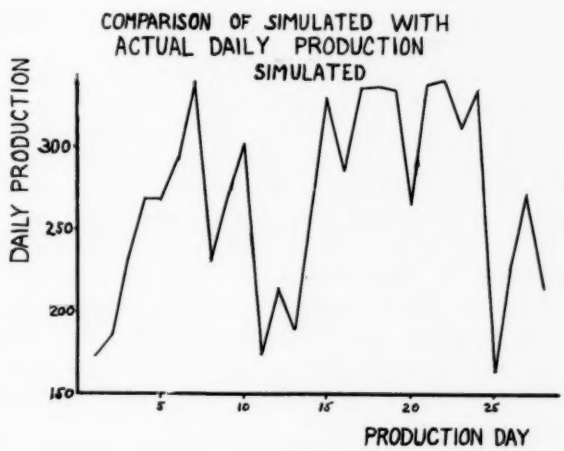

Fig. 6

Figure 5 shows the output of the real line for a typical one-month period. Figure 6 shows the output of the simulated line for a like one-month period. The two sets of production statistics appear that they could easily have come from the same line. The one low day of production from the computer line is accounted

for by the fact that there was no point in the program where, if absences, quits, or downtime got bad enough, the line would be shut down for the day! This is what probably would have happened in the real case. The low production in the first few days of the computer operation was caused by new workers learning the job. The data from the fourteenth to the twenty- fourth in the simulation looks very much like the data from the real line for the first fourteen days.

FUTURE PLANS

With the line constructed and at least in some gross sense behaving like the real world, it is now possible to experiment with various line configurations. The initial tests are tests of the effect of changing line length. This is one of the major unanswered questions of production line design. Next, the other factors will be statistically varied to discover their effect on productivity. This is important, since if we can establish that the model is never sensitive to a factor, that factor can be eliminated and the model simplified.

After the model is thus tested out, we have plans to invite several industrial managers to help us manipulate the line to determine more effective line configurations.

None of these tests have validated the generality of the model. We intend to test the model with the rules and data from several other, perhaps less general, industries. To this end, tentative arrangements have already been made with an electronics firm and a clothing firm.

From such a study it may be possible to develop an analytical solution to the problem. If this is not possible, it may at least be feasible to make some generalizations about the operations of the line. Perhaps it will be possible to draw up tables and certain rough guides for line design.

One of the specific goals of this project is to try to insert some of the psychological and motivational constructs into our model of line operation. Trying out different hypotheses in this area may be one of the most interesting uses of the model.

It seems clear that this is a cheap, practical and useful technique for studying this kind of industrial situation. The time required to simulate line operation for a day depends upon the cycle time; the simulation of the actual appliance line took about one and two tenths minutes per day on an IBM 709 computer. If the less important factors were removed, it could take considerably shorter time.

It seems certain that tests will show that many of the factors currently considered as important will not really matter. The knowledge that they have no effect should be a useful contribution not only to the literature of the field, but to production people who are currently using these concepts.

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ON THE EMPIRICAL DESIGN OF MANAGEMENT CONTROL SYSTEMS

By J. B. HEYNE

Manager, Management Control Systems Research System Development Corporation

INTRODUCTION

FOR THE past two years, the System Development Corporation has sponsored a research project whose object is to study the impact of computer technology on managerial activity. By January 1, 1961, about fifteen professional man-years had been spent in this System Development Corporation - Management Control Systems (SDC-MCS) study. A major result of this work has been the development of a computer program. This program enables a digital computer to serve as a research vehicle.[1] It can then be used in the empirical design of controls for any activity which can be rendered into a particular meaningful form. It has been both necessary and possible to develop a definition of controls which lends itself to quantification in this context. To be susceptible to the empirical design of such controls, an activity must meet two conditions. These conditions are:

1. That the activity lend itself to being phrased as a network of tasks, with queues being associated with each task. These queues hold tasks yet to be done or tasks already completed.
2. That the parameters of control surrounding each task be explicitly stated and the alternatives be postulated. These alternatives are necessary in order that empirical design can be effected.

1. One foreseeable use of such a device is to permit managers to anticipate the effect of changes which are controllable by management and to choose quantitatively between alternatives. This use results from the ability of the digital computer to compress time. A manager, in a matter of minutes, can observe a simulated year of operational experience, make managerial changes, and observe the effect of the changes made on any aspect of his operation.

DEFINITION OF TERMS

The word "task" used in this context carries with it a connotation of homogeneity. The activity of a Sales Manager, for instance, in signing off proposals is construed to be one task. This is the case even though the Sales Manager may allocate a sales budget, hire salesmen, and call on customers, in addition to signing off proposals. Each of the different activities so described would require that a separate task be modeled. The Sales Manager himself would be regarded as a task center.

In digital computer programming, a task is a series of logical operations. As a model of an activity is being created, it is necessary to express logically each step which is to be performed in the task, or series of operations.

This paper does not hazard a rigorous definition of management control. It is nonetheless possible to approach a useful definition by realizing that which would be controlled must first be measured, and that which would be measured must first be identified. It is in this sense that a set of parameters of control useful to the purpose of empirical design can be established.

There are six explicitly identifiable control parameters for each task: Allocation, Selection, Decision, Information Sensing, Recording, and Organizing.

The first control parameter is the manner in which the resources are allocated to a particular task. For instance, where a Sales Manager has five or six different tasks to perform, the matter in which he allocates himself as a personnel resource is an identifiable

control parameter. Alternatively, if the Sales Manager has available to him a working force, the manner in which personnel are assigned to various tasks is an identifiable control parameter. This means that there are some allocation activities which may be phrased as separate allocation tasks.

The second control parameter is the manner of selecting the next task to be performed from the waiting queue of tasks.

The third control parameter is the application of a particular decision rule algorithm, or control mechanism, which specifies how the selected task shall be performed.

Associated with any particular control of decision rule algorithm are specific pieces of information. The fourth control parameter identifies the manner in which associated pieces of information are to be sensed.

The fifth control parameter is the decision as to whether or not to record what was done in the performance of the particular task.

The sixth control parameter is the direction, through the organization, of processed information developed by a particular task.

Identification of these control parameters for each task is necessary to satisfy the second condition required if controls are to be empirically designed using the SDC-MCS research vehicle.

SYSTEM ANALYSIS TECHNIQUE USED

The classical electrical engineering method of studying complex systems requires that their inputs or outputs be specified and that mathematical representations of system transfer functions be defined. The SDC-MCS work has taken place without it being possible so to define these characteristics of the system under study. Indeed, any attempt to define the transfer functions of a business or to list its output comprehensively will be a highly subjective undertaking for some time to come.

In studying the general case, the SCD-MCS study undertakes system analysis without such a predefinition of input, transfer function, and output. Instead, a set of variables has been identified which are ambient in the operating system. The digital computer has been programmed in a manner which effects a time trace of each of these variables through any simulated time period. The output of any experimentation using the SDC-MCS research vehicle, is therefore a set of time series. There can be as many time series as there are identified variables. The relationships between these variables, whether they are to be established in the same time frame or across time frames, can be inferred statistically. In this manner, the output of the research vehicle is rendered in a form useful in drawing quantitative conclusions. The SDC-MCS computer program thus enables a series of snapshots of the variables which identify system activity to be taken periodically. In each of these time-dependent snapshots, the value of each of the variables is recorded on magnetic tape. This enables the printing out of experimental results to be accomplished off-line, without using undue amounts of expensive computation time.

TASK ORGANIZATION - MANNER MEANINGFUL TO USE OF DIGITAL COMPUTERS

Tasks may be designed so that they consume simulated time, in which case they are called Variable Rate Tasks. Other tasks may be designed in the simulation without having simulated time consumption associated with them. These tasks are called Nonvariable Rate, or Zero Time, Tasks. Sudden allocation of the budget, for instance, might be a Zero Time Task.

Figure 1 describes task construction as it is meaningful to the computer program in simulation. This figure identifies homogenous task characteristics and describes how the computer simulates time. Every task which consumes simulated time must be represented by a Variable Rate Task Control Block. Tasks are Variable Rate when they use a simulated amount of time. The time used is proportional to the resources allocated.

Every variable rate task subroutine (a manager looking at an order, a machine processing the manufactures in the plant) is programmed in two phases: Set Up and Completion. The reason for this organization within the computer is to allow the program to predetermine (during the Set Up phase) whether necessary resources are actually variable before proceeding with the simulation of a task. This is necessary to prevent the simulation of tasks which could not take place under real

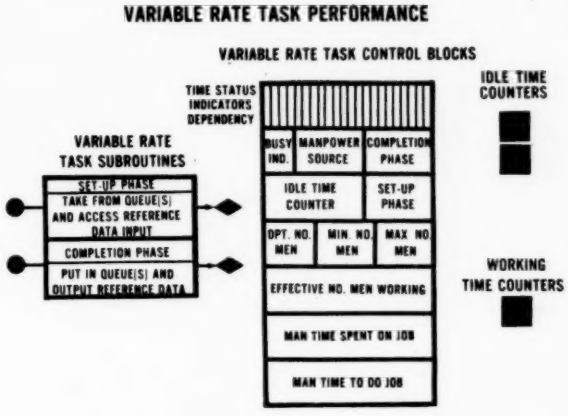

Fig. 1

conditions, for reasons such as no people, no material or no facilities having been made available to the performance of the task.

In order to perform the Set Up and Completion phases at the proper time and to facilitate the homogeneous control of tasks by tasks, the following information must be in the Task Control Block:

1. Working tasks are indicated by a BUSY indicator, set by the basic cycling routine.
2. Identification of the type of resources allocable to the task.
3. The symbolic location in the computer memory of the Set Up and Completion phases.
4. The address of counters which record unproductive resource allocation. Addresses enable these counters to be located in the computer memory. Counters accommodate interest on the part of the experimenter in the measurement of idle time.
5. Maximum possible resource allocation.
6. Minimum possible resource allocation.
7. Actual resource allocation.
8. Effective resource allocation is indicated separately so that differences from Actual can be measured.
9. Resource time to do the task.
10. Resources present.
11. Resource time expended.

Tasks may be in any one of four general states at any given time. These states, as shown in Figure 2, are Set Up, Idle, Working or Completion.

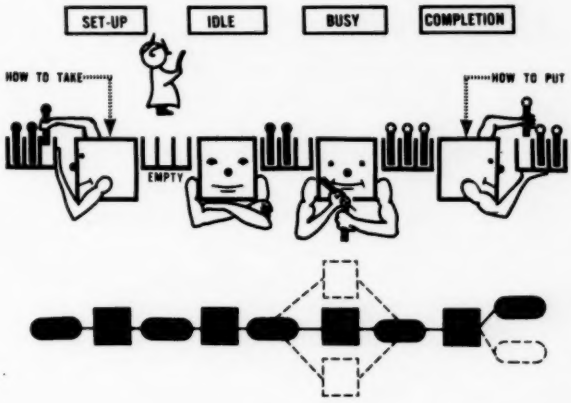

Fig. 2

Set Up - If a task has an item in its input queue and has allocated to it the resources necessary, it is said to be in the state of Set Up. During the Set Up phase of a task, work to be done is taken from a queue, and the required reference data is sought. Resource allocation and removals from a queue are made in accordance with an explicit discipline during this phase.

Idle - A task may be idle because resources have not been allocated or because its input queue is empty.

Working - This is a self-descriptive state.

Completion - In this state, the task puts into a queue that which it has finished, and outputs reference data which has been computed in the performance of the task. The time taken to do the operation is the delay between the Set Up phase and the Completion phase.

Queue-task systems may be illustrated in flow form as indicated by the diagram at the bottom of Figure 2.

In order to facilitate the analysis of a model built of queues and tasks, the computer program contains various subroutines, each one designed to perform some particular service. These are communicated with by means of macro instructions in the computer.[2]

2. A more exhaustive discussion of programming details is included in "SIMPAC, A Research Tool for Simulation," SP-228, M. R. Lackner.

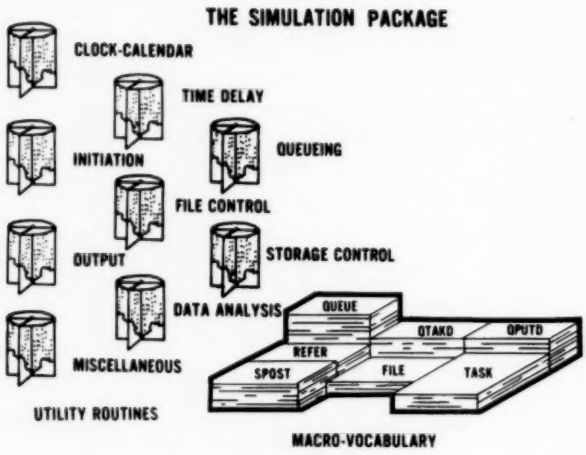

Fig. 3

Figure 3 lists some illustrative macro instructions. Some macro instructions communicate with SDC-MCS computer subroutines so that the service which they are required to perform can be introduced symbolically to the computer. Other macro instructions do not communicate with subroutines, but generate data tables or handle repetitive coding operations. For instance, one macro generates a queue. Repeated use of this macro generates many separate queues.

Description of Macro Instructions Listed in Figure 3

CLOCK AND CALENDAR TIMEKEEPING - Permits records to be kept of the simulated passage of time.

TIME DELAY - Permits delay in simulated transmission of task-generated information.

INITIALIZATION - Makes it possible to preload the queue-task system. Possible system transient effects are eliminated by such preloading.

FILE CONTROL - Controls the amount of information being recorded during simulation.

OUTPUT AND DATA ANALYSIS - Records the state of a file at a fixed time so that it may be used for data analysis during the output phase.

"QTAKD" - Says to the computer, "Take from queue x according to discipline located at y."

"QPUTD" - Says to the computer, "Put into queue x according to discipline located at y."

"REFER" - Tells which file a task should refer to. This file itself is generated by a macro instruction. This "FILE" macro describes the file in terms of length and number of previous time records which were kept.

"TASK" - Generates the basic structure of a task. It accomplishes the taking from a queue according to a discipline, putting into a queue according to another discipline, expending the necessary time to serve the transaction.

"SPOST" or "APOST" - Effect additive postings to a variable which is located in the reference file. These are used in association with "TASK."

TASK ORGANIZATION - MANNER MEANINGFUL TO DESIGNERS OF CONTROLS

Figure 4 is an orthodox representation of an activity. Offices, factory, warehouse, shipping dock, and warehouse receiving dock activities are shown.

Figure 5 shows such a company represented as a queue-task network in the manner developed in Figure 2. The diagonally striped hexagons represent environmental activity.

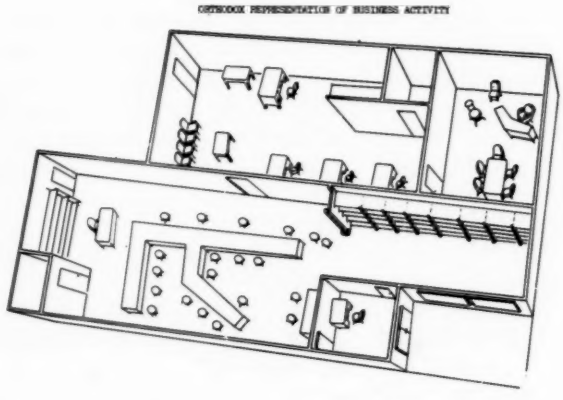

Fig. 4

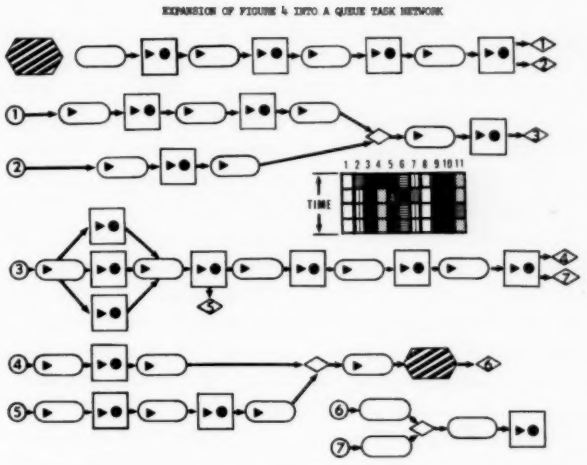

Fig. 5

The environment is defined to include those factors which are not affected by the choice of particular parameters of control. Vendors, competition, customers and banks are illustrative environmental activities represented in the model by transfer functions. In the interest of program simplicity, preliminary modeling efforts restrict the complexity of environmental transfer functions to third-order polynomials. The upper left corner of Figure 5 represents the generation of incoming sales orders. These orders become transactions.

Defining a transaction is difficult. In queuing theory terminology, a transaction corresponds to a candidate for service. In the context of the SDC-MCS study, with a network of tasks having been postulated, transactions may be defined as discrete computer words containing separately grouped areas of information. These words have a propensity to form queues at the places where they are operated upon by tasks. The propensity to form queues is a function of the rate at which transactions arrive at a task and of the rate at which they can be operated upon.

The lower right corner of Figure 5 represents the task of paying for received shipments. This is an environmental task since it is performed by the customer.

A parameter of control in the form of queue disciplines can be exerted upon a queue-task network at every location shown as a triangle in Figure 5. For each of the tasks shown as white squares in Figure 5, it is possible to state in what order transactions will be taken in the next task. At every queue location it is possible explicitly to control the order in which transactions shall be inserted.

A record of the queue disciplines in use at each task during a given experimental run exists in a reference file. Reference files record information. A representation of a reference file is shown in the center of Figure 5, with most current information shown at the top of each numbered task record. Such records may have current or increasingly older information represented. For example, a task may be restricted to the use of the latest information about the queue discipline in use at a particular task, older information about the discipline in use at another task, and obsolete information about the disciplines in use at still another task.

A given control rule is restricted to the use of information of a given quality as shown in the central part of the figure as a heavily shaded square. This is descriptive of the ability of the computer to simulate time delays.

Small circles at each task location in Figure 5 indicate tasks which are sensitive to managerial control in the form of resource allocation. Information of varying quality about resource allocation is contained in the reference file. Quality of such information about such allocation is shown by the difference in intensity of the horizontal shading.

Reference files also contain information about environmental activity, shown in Figure 5 by vertical shading. Although control cannot be exerted upon environmental tasks, information about the environment is available. This information may be of varying quality.

In addition to ambient information, which is the actual record of current conditions, other information may be generated. For example, projections or budgets may be generated using information available in the reference file. This new information becomes available for other tasks and varies in quality as shown by the density of the dotted shading in the figure.

Task definition for use in the SDC-MCS model must comply with the following requirements. To describe a task, it is necessary to identify:

1. The input queue.

2. The task selection discipline.
3. Time consumed in man-hours per transaction, either as a fixed integer value or as $N/\mu/\sigma$, which, for example, would call out a normal distribution of mean μ and standard deviation σ.
4. Idle time counter location.
5. Work time counter location.
6. The minimum number of people necessary to the task.
7. The maximum number of people allowable.
8. The actual initial number of people assigned.
9. Records to be kept.
10. The output queue.
11. CNMCH, the control mechanism (algorithmic representation of a decision rule).
12. The sources of each variable used in CNMCH.

In modeling of ongoing activities, it may be expected that actual operational decision rules will be hard to define. In effect, a wide variety of given rules at a task may be postulated; and the people exerting these rules may admit to a random choice from the simulation of postulated rules. This effect can be simulated by inserting into each task a mechanism enabling the random selection from a family of alternate decision rules.

It must be noted that the same mechanism which allows for random selection can also be used to endow the model with the capability of dynamic change in the choice of decision rules.

BASIS FOR SDC INTEREST

Before entering on a particular discussion of how operational tasks in an ongoing business can be defined, it is perhaps necessary to describe the System Development Corporation in order to explain why the SDC-MCS model is not a description of a real operating company. SDC is a nonprofit corporation dedicated to the public interest. It is an off-shoot of the RAND Corporation. The RAND Corporation was conceived about 1944 by the late General H. H. Arnold.[3] He called for the establishment of a group whose purpose it would be to engage in long-range planning for the U. S. Air Force.

Behavioral scientists working at RAND perceived that the Air Force of the 1960's was going to impose new technological requirements on Air Force personnel. These requirements were to be met by a group of boys whose preparation was not to differ very much from the preparation of those who had entered the Air Force in 1940. As such weapon systems as ballistic missiles and SAGE were contemplated, it was determined that there would be need for special training for those who would be entering the Air Force during the present and future decades.

The SAGE program, the Semi-Automatic Ground Environment, was chosen as a specific study program in personnel training. The major effort under this study program was to find an alternative to the required repeated use of airborne B47 and B52 bombers as a method of training SAGE radar operators.

One approach which has been successfully exploited in this study has been to code magnetic tape inputs to digital computers. The effect of an air attack would show up in a realistic manner on radar screens. In this manner, it becomes possible to test individuals, small groups, sectors, and indeed the entire North American Air Defense Command. It is possible, iteratively, to improve the operation of the Command in its several parts with each iteration of the experiment. This can be accomplished with a minimum of actual flights.

The System Development Division of RAND,[4] which had carried on this particular work, became the System Development Corporation.

By 1959, some interested people began to question whether the techniques used by SDC in upgrading the technology of Air Force personnel might not be applied to the industrial community. Clerical man-machine interactions had by that time long been under study. It was not construed that SDC participation in this area was justifiable. However, studies related to managerial man-machine

3. A more complete history is available in "Project RAND," *P-707*, F. R. Collbohm, March 24, 1955; and in "The System Development Corporation and the System Training Program," *SP-52*, L. F. Carter, February 6, 1959.

4. "The Story of SDD," *SD-1094*, F. N. Marzocco, October 1, 1956.

interactions were judged to be properly challenging.

For the purpose of performing such studies, the Business Management Control Systems Research Project (BMCSRP) was initiated in January 1959. In March 1959, Alan J. Rowe joined SDC to become Manager of this project. On November 1, 1960, Dr. Rowe was succeeded by Jay B. Heyne. Dr. Rowe is now Director of Industrial Dynamics Research at Hughes Aircraft Company. The program is now designated the Management Controls Research Project.

As a nonprofit corporation, SDC is constrained from participating in activities which might be construed as contributing to the profit of any particular profit-making organization. It has therefore been necessary for people working on the SDC-MCS project up to this time to invent a typical activity. In the invention of a business, it has been necessary, arbitrarily, to choose business characteristics. Various operable control rules have been inserted in the business. The operable rules in the preliminary model are not offered as being best or optimal for such an organization as was created. Provisions have been made for experimental change of these control rules, either dynamically in a given run or sequentially over more than one run. A method and notation has been developed to facilitate the change in variables and parameters necessary in implement either of these modes of change.

DESCRIPTION OF THE PARTICULAR ACTIVITY INITIALLY MODELED

An orthodox organization chart of the invented company, created to establish the SDC-MCS research tool concept, is shown in Figure 6. In the case of the invented company, the activities of the President and the Controller have been combined. This company has an annual volume of $30 million. Ninety per cent of this volume results from the sale of four models of a standard product produced to inventory; ten per cent of this volume is from special orders. Special orders are received from customers after proposals have been written in response to Requests for Proposals. Special orders come into the Sales Department. They are sent to Engineering Design, then to Production Control. There they are

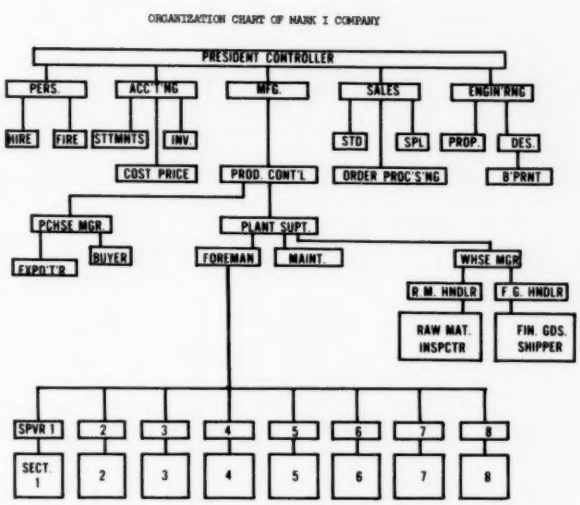

Fig. 6

combined with standard orders and sent through the Manufacturing Plant. The Production Controller also serves as a Manufacturing Director, who controls the Purchasing and Warehousing Departments. The Warehousing Manager is responsible for both finished goods and raw materials. A Plant Superintendent, who works for the Production Controller, also supervises maintenance activity. A General Foreman is included, to whom report eight Section Supervisors for the eight manufacturing departments of the Manufacturing Division. Different product models are sent through different departments, posing a scheduling problem in this company.

An Accounting Department is maintained, and it renders statements, invoices, maintains inventories, and develops prices.

The Personnel Department has a recruiting and termination function, and maintains departmental records for 1600 people who are employed.

The places where time is consumed in this series of figures do not correspond to the individual tasks defined in the early sections of this paper. In this respect Figure 7 is useful. The elliptically encirlced task areas identify task centers such as Sales, Order Processing and Production Control.

Figure 7 represents a simplified version of some of the major transaction flows through the Mark I system. Beginning with the standard order transaction, it is seen that generation

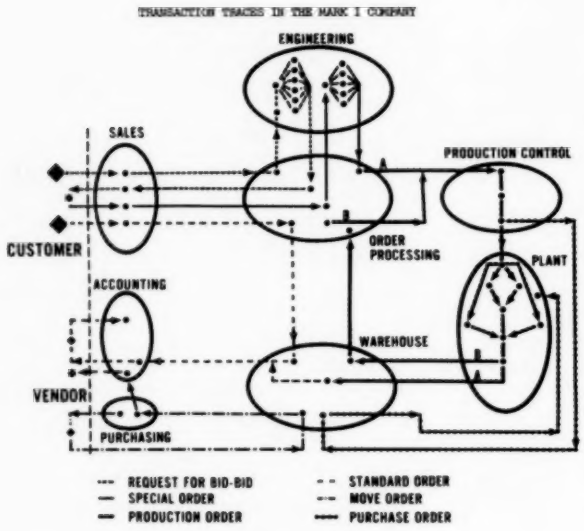

Fig. 7

occurs in the environment, presumably by a customer. Having been generated, a standard order appears in a queue in front of a task in the Sales area. Each task is shown as a large dot. Task centers are shown as groups of tasks and are arbitrarily named.

For each of the six transactions shown in Figure 7, the arrows trace how individual tasks can be identified. These are listed in a manner in which they might occur in a relatively simple manufacturing organization.

Figure 7 is a subjective representation of the variables which have been described as being necessary to the generation of meaningful output. In the case of the Mark I Corporation, the same activities as have just been described in Figure 7 are shown in Figure 8. These are Sales, Engineering, Manufacturing, Administration, Warehousing, Purchasing, Factory, Personnel, Accounting, Financial Management, Budgeting, and Pricing.

In terms of ambient variables in a business system, three-letter descriptors have been used in the preliminary model.[5]

This subjective representation will be developed in the course of the next nine figures into a time-sliced snapshot of the company. The purpose of the next section of this document is to show how a photograph can be taken of a company frozen in time.

Figure 8 in particular treats with the manner in which sales are developed. Two potential demands are postulated. These are, respectively, XNM for special sales and XNN for standard sales. Operating on these respective potential demands are two sets of six transfer functions. These describe the following relationships for special and standard products, respectively:

1. Price and potential demand, ISP and ITP
2. Quality and potential demand, ISQ and ITQ
3. Delivery lateness and potential demand, ISL and ITL
4. Advertising and potential demand, ISD and ITD
5. The number of salesmen and potential demand, ISC and ITC
6. The level of sales support and potential demand, ISO and ITO

The development through the next nine figures of the final time slice snapshot of a business (shown in Figure 16) is a description of how sales are affected by changing the potential demand characteristic.

Figure 8 shows that the volume of Special Orders, SAG, is combined with the volume of Standard Orders, SAB, to form SAD, the total volume of orders. These are taken through the time delays, TGD, TGE and TGF, which are the waiting, processing and holding times, respectively, of that accountant who develops AAG, accounts receivable.

Figure 9 traces how variations in quality affect the course of operations in the Mark I Corporation by affecting the state of the variables in the business, and, in particular, how variations in quality affect potential demand. Following from the transfer functions which

5. A more detailed discussion of this aspect of the model is made (without the use of figures) in "Mark I Operational Specification," *TM-536*, Jay B. Heyne, December 9, 1960. This method of notation too has been improved as described in "Symbolic Notation and Logical Operators for MCS Simulation," *FN-(L)-4529-1*, S. S. Ackerman and J. Kagdis; "Justification for the Symbolic Description of the Budget," *FN-(L)-5014*, S. S. Ackerman, January 23, 1961; and "Symbolic Description," *FN-(L)-5017*, S. S. Ackerman, January 23, 1961.

SUBJECTIVE REPRESENTATION OF SALES FUNCTION IN MARK I

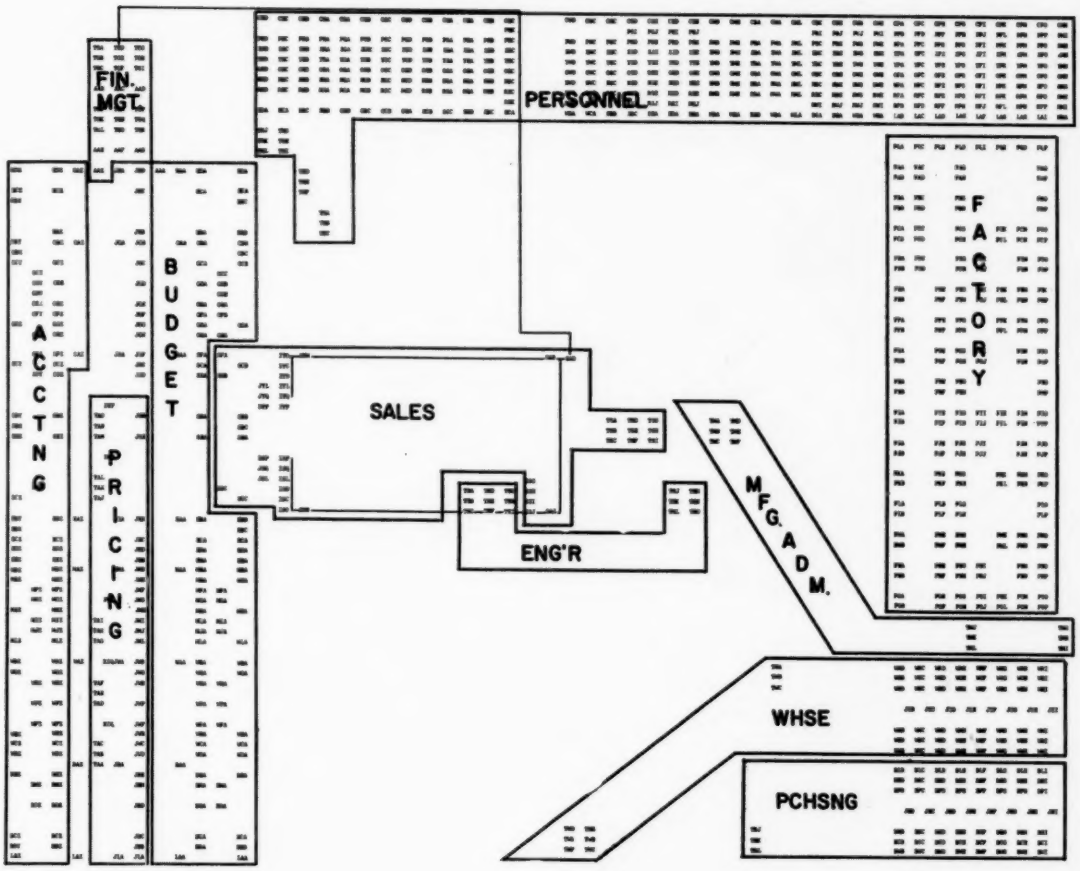

Fig. 8

relate potential demand and quality, the first place that quality is affected is at the area of the Purchasing Manager. In this place, waiting, processing and holding times TDJ, TDK and TDL are consumed while the Purchasing Manager makes a decision concerning the proper combination of price, quality, and delivery characteristics. The choice of vendor characteristics he makes gives some quantitative measure of the effect of such choices on system vendor interaction and of system reaction itself. Depending on the rule the Purchasing Manager chooses to follow, some quantity of defective material is delivered to the loading dock. This is designated JNi for each i^{th} material of the eight used in the factory of the Mark I Corporation. A decision by the Warehouse Manager as he consumes waiting, processing and holding times TWA, TWB and TWC will determine the sampling level of incoming inspection. Time for such inspection is comsumed for the i^{th} material as this time is used to inspect the JNi rejects which have come in. Inspection results in a JIi number. The amount of material defects has therefore been identified which can be expected in the operation of the Mark I Corporation. To the material defects must be added the workmanship defects which will occur in the factory.

Workmanship defects develop as a function of the effectiveness of the various people in the Factory Department, ZAA for the AA^{th} department. (It will be noted that personnel files in the Mark I Corporation are kept on a departmental, not on an individual employee, basis.) Such defects are a function of employee

SUBJECTIVE REPRESENTATION OF PRICE DETERMINATION IN MARK I

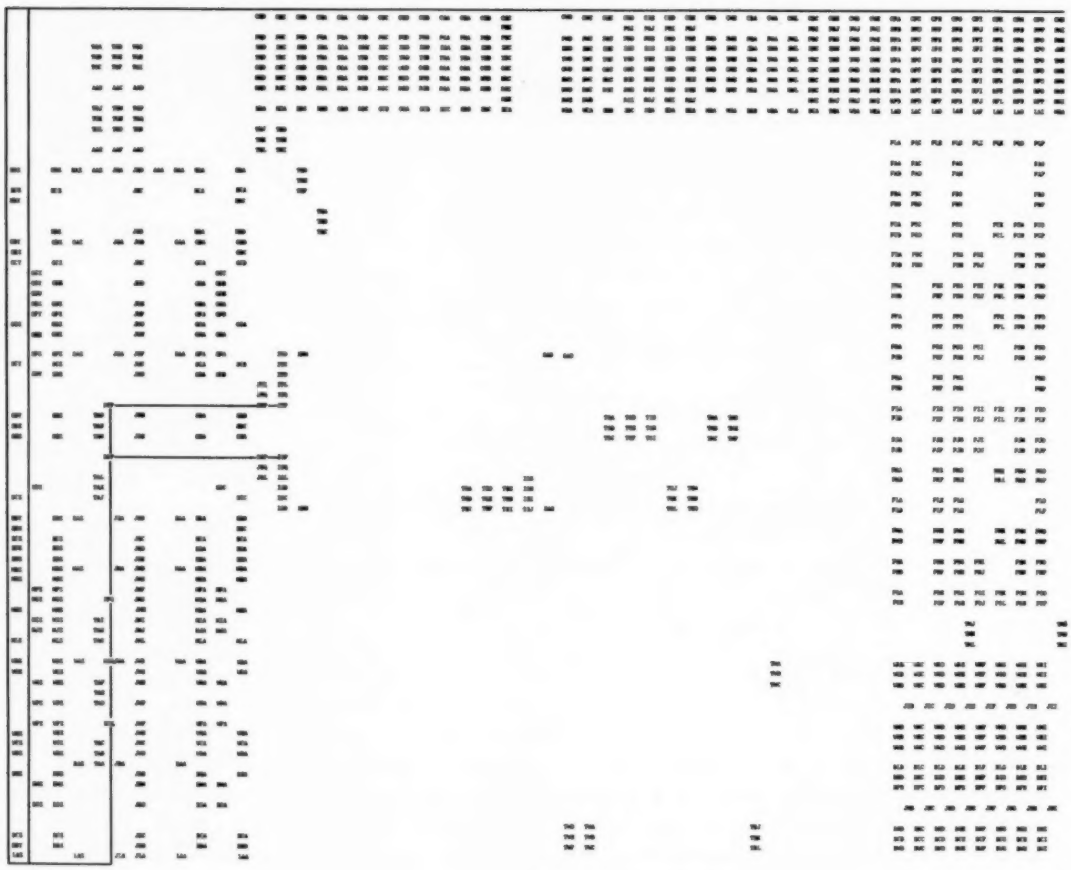

Fig. 9

departmental effectiveness and are combined with material defects in a manner shown in Figure 9. They develop for both standard and special products an amount of material rejected by the customer because of poor quality. This per cent of rejection by the customer operates on the transfer function which relates potential demand and quality. Quality is thus shown to be a factor in determining the state of the variables at any time in the course of operating a business.

Figure 10 shows how a pricing decision rule affects the ambient variables. The pricing decision rule[6] used in the Mark I Corporation says that price shall be determined on the basis of cost. Periodic costs shall be summed by taking as output from all Departmental Personnel Records information as to how much was charged by this activity. Employee fringe expenses are added, down the left side, to nonsalary associated expenses. These are combined at the bottom of Figure 9 as shown with times TAA through TAO where overhead rates are computed and added and incremental profit margins are added. Finally price is developed. This is an input to the transfer functions which relate price and potential demand.

Figure 11 begins the description of how budgets are allocated. The decision rule effective in the preliminary version of the Mark I Corporation says that budgets shall be allocated on the basis of the percentage of expenditure of the previous period; and the lines

6. FN-(L)-5014 and FN-(L)-5017 (see reference 5) list alternate decision rules for pricing, budgeting, scheduling, and forecasting. These shall be introduced as experimental alternatives.

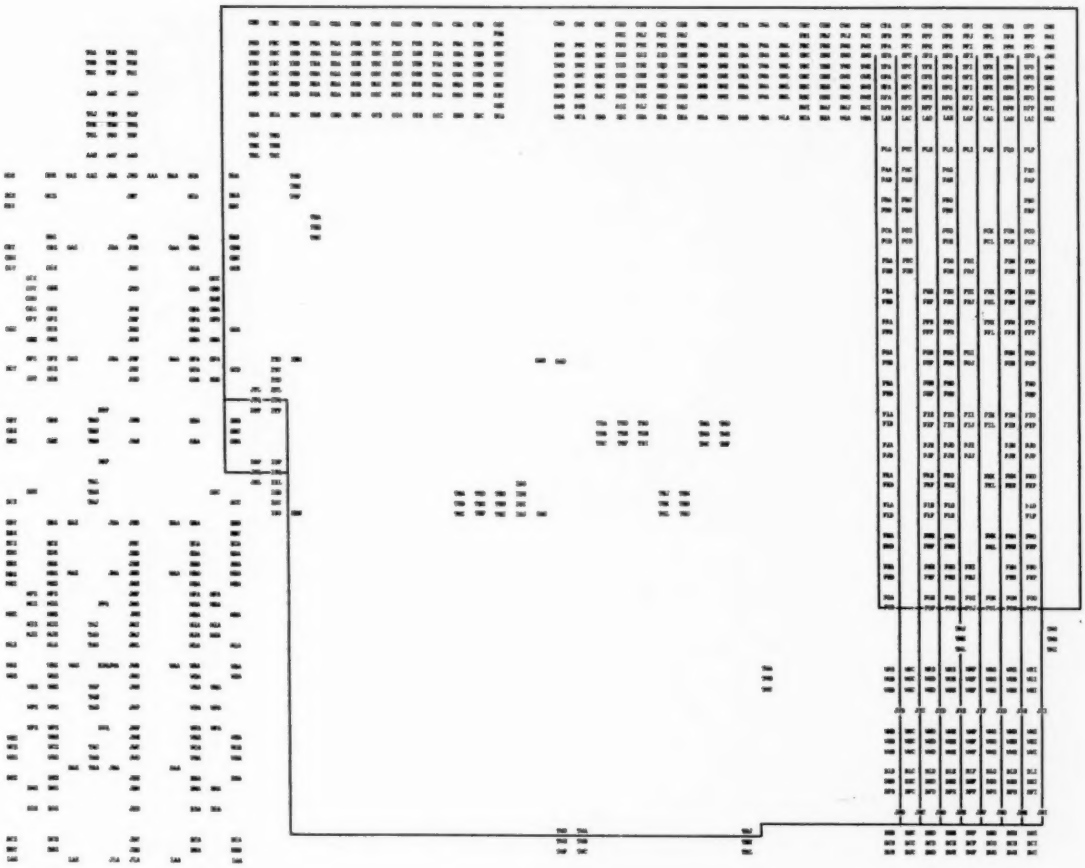

Fig. 10

shown in Figure 11 are a reflection of how accounts are debited against their allocated budget expenditures.

Figure 12 shows the actual computations involved in allocating budgets based on previous period expenditures. A computation of the total operating fund requirements during the next time period in the area of Financial Management determines whether it shall be necessary to borrow. Once this has been determined, the percentage allocation takes place in the manner shown in Figure 12.

Figure 13 shows the actual budget allocation techniques. To establish some symmetry in the figure, those places where people associated with the budget consume time (and form task centers) have been shown. Lines have been drawn from the Budget Allocation area through the places where time delays are associated by the presence of budgeted people to the various Personnel Department files. In this manner, the pervasiveness of the Budget Allocation Rule initially programmed into the Mark I Company becomes apparent. One further point might be added here: Those transfer functions which relate advertising and potential demand, the number of salesmen and potential demand, and the sales support expense and potential demand for both standard and special products are determined by the budget allocation rule. To this extent, then, actual sales are a function of the budget allocation.

Figure 14 follows upon the statement made concerning Figure 13 that all budget allocations are shown as inputs to the Personnel

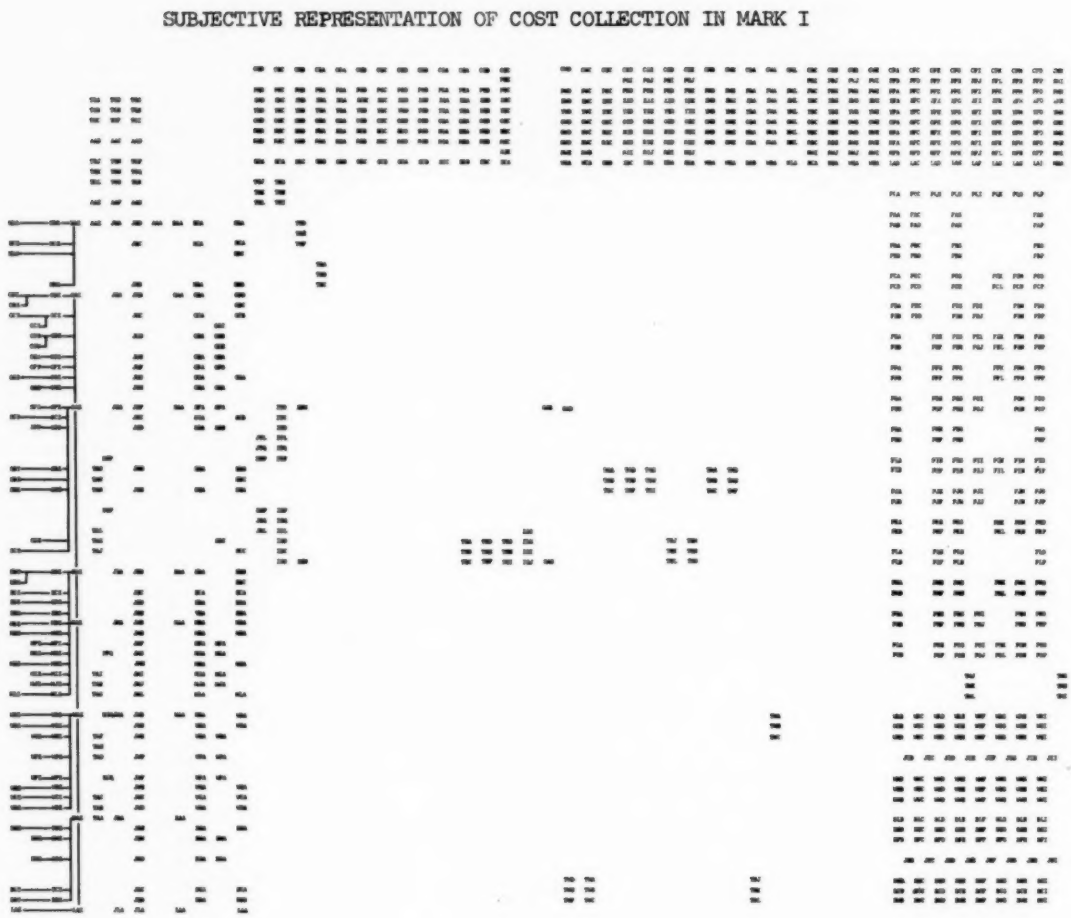

Fig. 11

Department. Reading from the bottom, the various records which are kept in Personnel Department files as shown in Figure 14 are:

Budget allocation
Overtime rate
Straight time rate
Number of people desired
Number of people absent
Number of people present
Effectiveness of people in the department
Number of people actually on the payroll
Idle Time
Total actual wage and salary charges

It will be noticed, too, that personnel activity controls each of the triplets - the variables shown here - which have been described as waiting, processing and holding times at the various activities. This is true not only in Sales, Engineering, Manufacturing and Administration, but also in Financial Management and in Accounting. This means, effectively, that personnel activity controls the number of service channels in the queue task network, and the individual channels are identifiable as people supplied by the Personnel Department. This, it must be added here, is a very subjective rendition which follows the way the Mark I Company has been developed.

Figure 15 follows upon the idea that time delays are controlled by activities in the Personnel Department to the extent that a percentage of late deliveries are developed. These are occasioned by time being consumed in the company. Changes in demand for both standard

SUBJECTIVE REPRESENTATION OF FUNDING REQUIREMENT DETERMINATION IN MARK I

Fig. 12

and special product are related to time consumption. By following Figure 15, many of the relationships shown in Figure 7 are repeated. Figure 15 is just another way of showing this transaction interrelationship. Figure 7 does not permit this view of movement through the Factory, which is shown as having four standard models and a number, set at 11, of special model routes through its eight manufacturing stations. One other fact becomes discernible: That the rate of expansion of the company, measurable by its ability to move material and information, is dependent in its rate of change on how fast the Personnel Department itself can respond to changes. The rate at which the Personnel Manager and his staff consume times THA through THL governs the rate at which the company can be expected to expand and contract.

Found in Figure 16 is the composite snapshot of how all of these variables interact. This interaction is complex, even for this unsophisticated set of decision rules. It requires resolution only by digital computation so that the course of a simulated year may be read out in a matter of a few minutes. If an hour is to be used as the time frame, a digital computer is the only conceivable tool which yields 2000 readings in the course of a simulated year, updates all variables, and causes the business output to be several hundred time series, each having 2000 readings, all in a few minutes.

METHODS OF DESIGNING CONTROLS

The manner in which parameters of control can be used in the empirical design of a particular control system is indicated in Figures

SUBJECTIVE REPRESENTATION OF BUDGET ALLOCATION IN MARK I
(Salary-associated allocations are drawn through the places in the system where people consume time, and from there these allocations are shown to be the input to the personnel algorithm.)

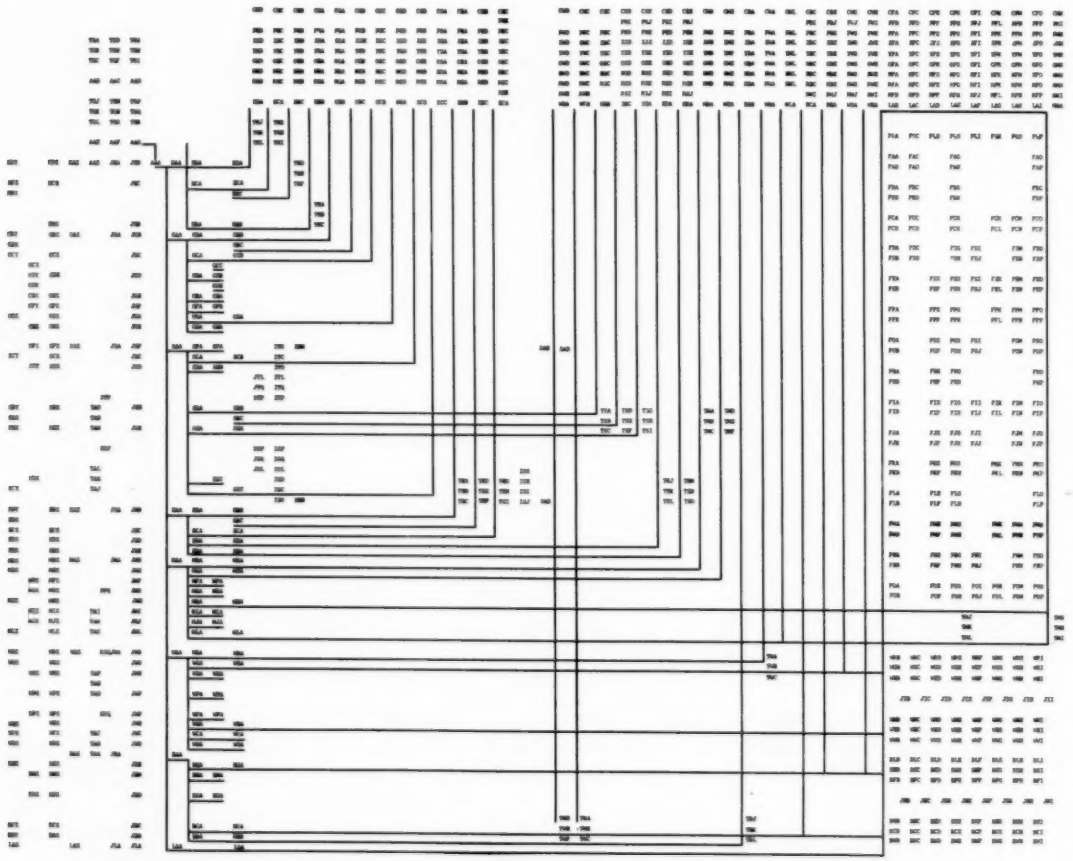

Fig. 13

SUBJECTIVE REPRESENTATION OF PERSONNEL IN MARK I

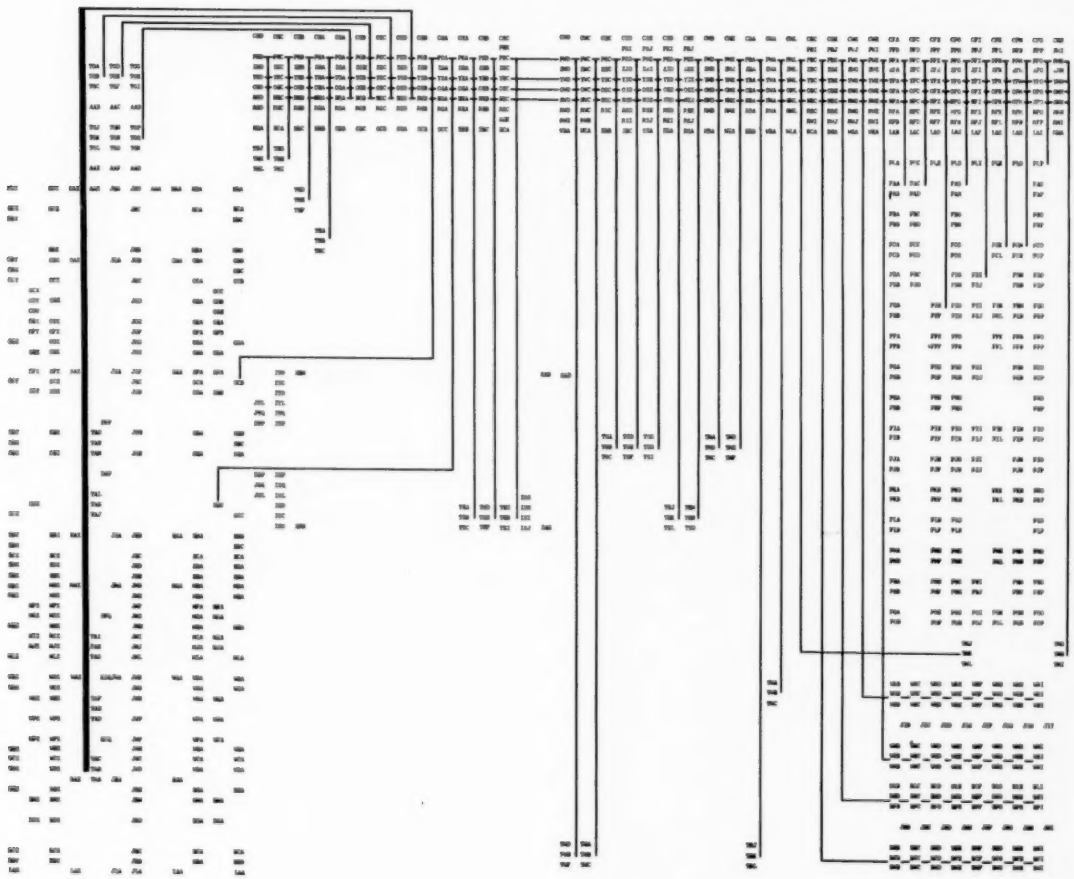

Fig. 14

SUBJECTIVE REPRESENTATION OF TIME DELAYS IN MARK I

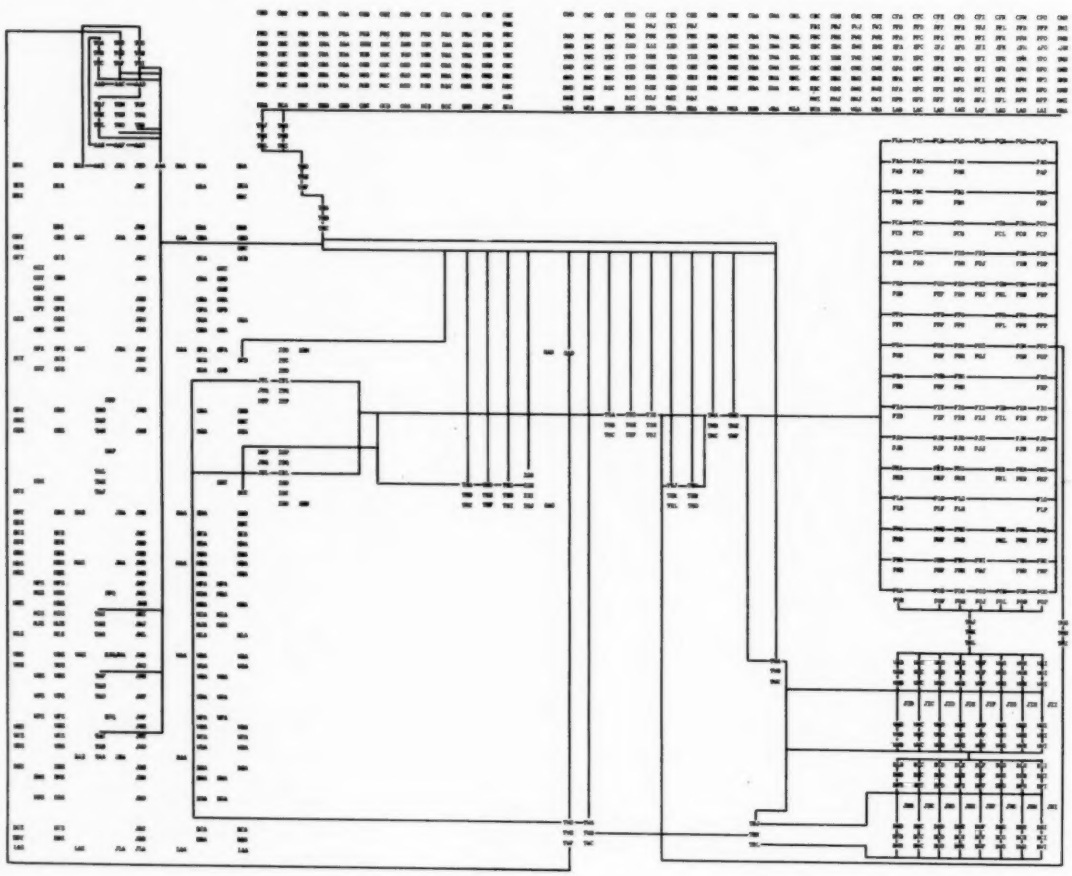

Fig. 15

SUBJECTIVE REPRESENTATION OF THE INTERRELATIONSHIPS EXISTENT IN MARK I
(This Figure can be conceived as a snapshot, at a given time, of the Mark I Activity System.)

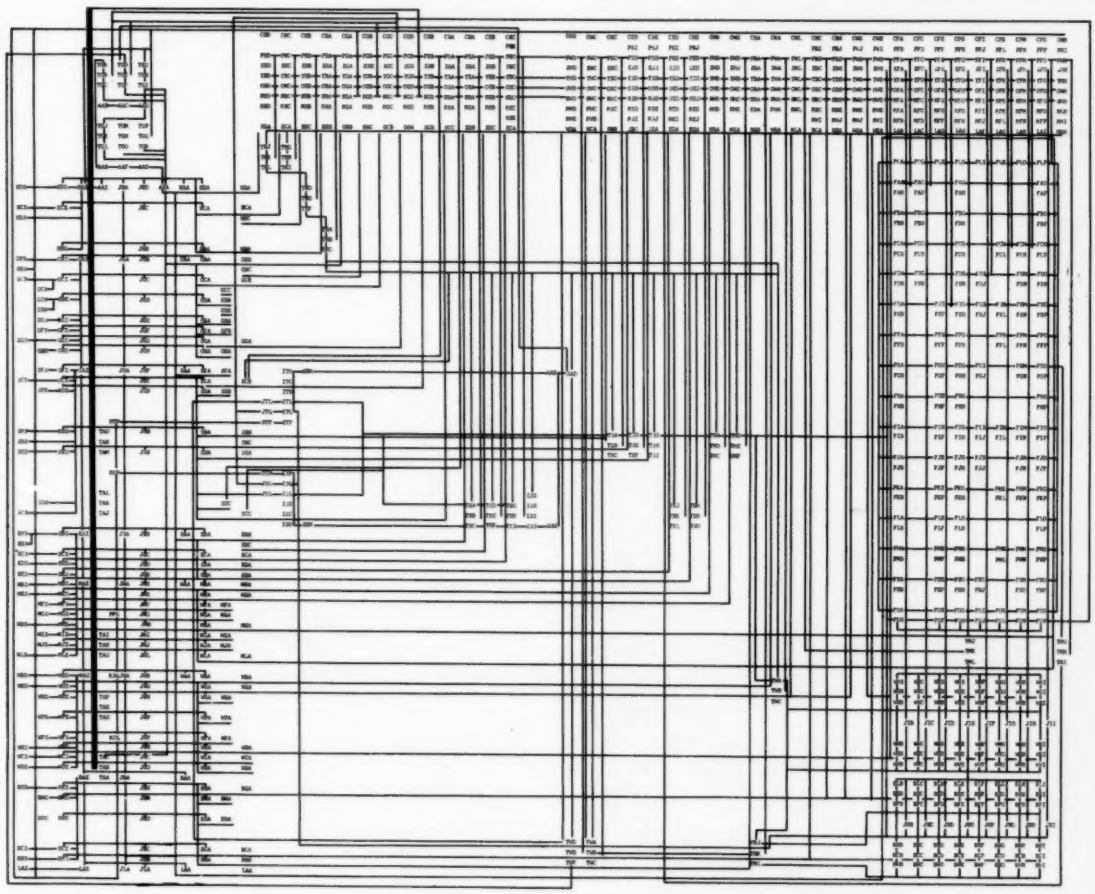

Fig. 16

QUEUING OF TASKS

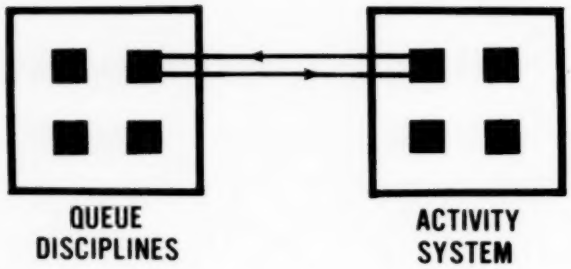

Fig. 17

17 through 23.

Figure 17 shows how at the onset of a particular task in the system, the manner in which the next task shall be chosen can be made explicit. This identification enables experimental variation of the manner of choosing the next task. Sequential experimental runs can then be made with alternative queuing disciplines, other factors being held constant. The effect of varying just the queuing discipline of a particular task can then be quantified in terms of the change on the output of the total system.

Figure 18 shows the range of choice of operational control mechanisms or decision rules using algorithms available. The various possible decision rule algorithms or control mechanisms are shown as part of the Control

TESTING OF CONTROL MECHANISMS

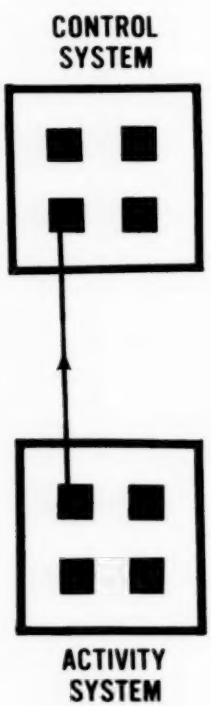

Fig. 18

CHANGING SENSING TECHNIQUES

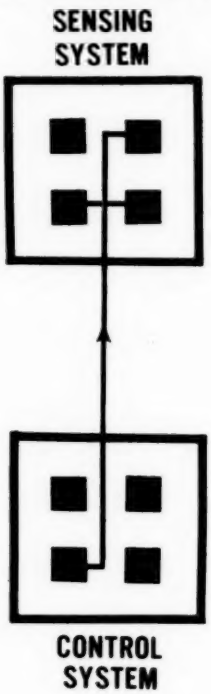

Fig. 19

BASIC INPUTS TO SENSING SYSTEM

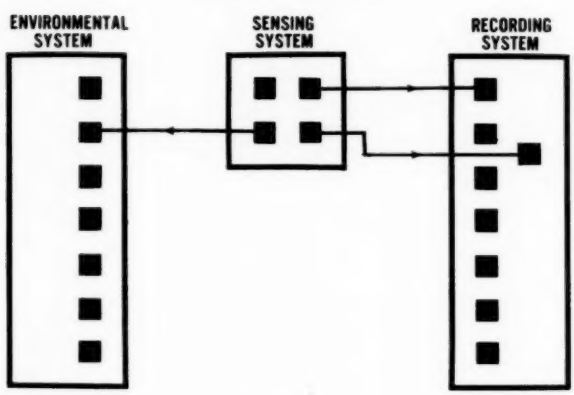

Fig. 20

System. In a sequence of experimental runs, other control parameters being held constant, various control mechanisms may be tested and their respective effect on total system output measured.

Associated with any particular control mechanism, as shown in Figure 19, are various informational inputs. The manner in which these are to be sensed and transduced into the Control System can be explicitly identified. Using this tool, changing of the manner of sensing any particular piece of information is possible. The effect of such a change can be measured on the total system output. This attribute of the research vehicle might be stressed with respect to intelligence systems.

Figure 20 identifies two possible places from where information might be sensed. These are:

1. The Environment - Defined as being included in the environment are those factors not controllable by the Control System being designed. The environment models such factors as customers, competition, vendors, unions and banks.

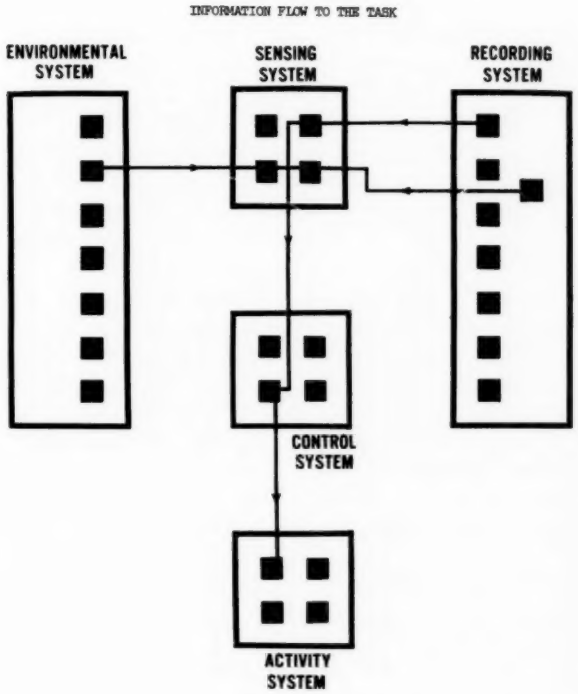

Fig. 21

2. The second place where information may be sensed is in the Recording System of the activity. This represents the files of the activity or, in the case of integrated data processing, it represents data stored in the computer memory.

Figure 21 traces backwards how information so sensed is returned into the sensing system and then into the Control System and finally to the task. Figure 21 does not mark the completion of the task.

Figure 22 shows how the explicit decision of whether to record the output of a particular

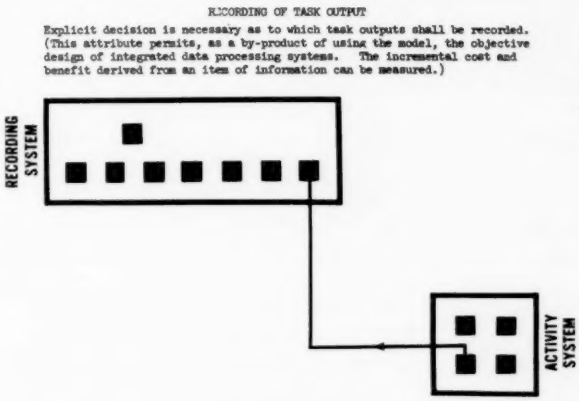
RECORDING OF TASK OUTPUT
Explicit decision is necessary as to which task outputs shall be recorded. (This attribute permits, as a by-product of using the model, the objective design of integrated data processing systems. The incremental cost and benefit derived from an item of information can be measured.)
RECORDING SYSTEM
ACTIVITY SYSTEM

Fig. 22

task can be applied to the design of an integrated data processing system. The incremental cost and utility of each additional piece of information introduced into the integrated data processing system can be quantified and measured. This Figure identifies a highly significant by-product of the SDC-MCS study. For the first time it becomes possible to design integrated data processing systems on the basis of incremental information value after the value has been objectively measured.

Figure 23 shows how changes in organization, which can be represented as changes in informational routing, can be effected experimentally. The effect of such changes can be measured on the output of a total system.

The techniques described above for analyzing any proposed organization for any system may be employed as an ongoing monitor in a system already endowed with operational capability. Continued evaluation of the

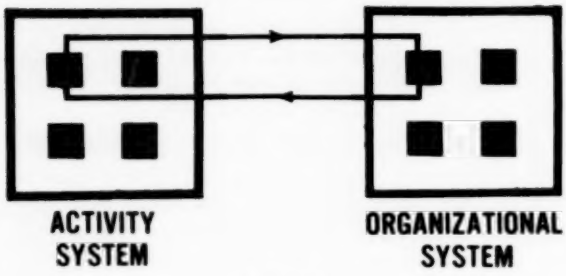

Fig. 23

performance of the system as well as examination of the potential performance under anticipated conditions is capability not now enjoyed by those who manage.

CONSIDERATIONS AS YET NOT RESOLVED

Exploitation of the SDC-MCS research vehicle depends upon further study and development of the following:

Validation Criteria. A mathematical technique is needed for quantifying the extent to which a network of queues and tasks validly represents an ongoing acitivty.

Aggregation Criteria. A mathematical technique is needed for developing quantitative criteria which allow for queue-task networks to be aggregated into subsystems. Such subsystems will have known measurable transfer functions operating or identifiable inputs.

Multivariate Time Series Regression Analysis Techniques.- It is not yet practical to identify general activity transfer functions operating on inputs to yield specific outputs. Because of this impracticality, the contemplated output of the current SDC-MCS program will be several hundred time series, each of separately identified variables, which change as a function of time as the system operates. Each series will have several hundred readings. Practical techniques for establishing correlations in time among such variables do not now exist. It is to be expected however that the development of regression techniques will enable to development of aggregation criteria.

Experimental Design. Any device capable of performing as the SDC-MCS program does, needs careful experimental designing using advanced techniques. These techniques must be studied because it is suspected that those available do not provide full exploitation of digital computer program capability.

Human Behavioral Criteria. Present and contemplated models do not provide for the simulation of human behavioral characteristics except to cause varying time delays for information transfer. Techniques for introducing human behavior patterns have yet to be developed.

Notation. Time used in conversion of phrased queue-task configurations into debugged computer code is being shortened by the development of an unambiguous notation which uniquely identifies variables used in business activity. Any notation for such identification can also be used to phrase system outputs into a consistent jargon; e.g., the notation can be used to resynthesize variables into an output that is meaningful to accountants, mathematicians, or managers.

CONCLUSION

By adhering to a rigidly imposed sequence of first simulating, then validating, and then improving (using this technique, it will be impossible to determine when optimization has taken place), it is possible to foresee the time when the computer program which uses simulated data on a simulated time basis can be used as an online control using real data on a real time basis. Should this ever occur, the best use of humans would result from assigning them to do that which they do best - to sense the ambient system environment and make judgmental-type decisions where necessary information does not explicitly exist.

Necessary modification to the current model has been planned for, as it has long been apparent that validation could only take place using real data.[7] It is anticipated that the

7. "Transaction Flow, A Checkout of the MCSR Business System Simulation Model," *FN-5135*, J. R. Crawford, is a description of how the acceptability of the initial model will be established. Validation of a hypothetical company is not possible.

present program will lend itself to such modification as the opportunity for validation presents itself. Once validated, the model may become a direct tool to be used in quantifying the effect of alternate management policies and rules.

Allowing for the validity of the previous two conjectures, a third remote possibility might be discerned. If a business system can be simulated, validated and optimized in a manner leading to the ability to aggregate its characteristics into macroscopic form, it might then be possible to study the interactions of two such systems by simulation. If such a two-system study can be validated, possibly a study of competitive industries can be made. This possibility leads to further conjecture concerning the characteristics of a given industry which might be so aggregated that the possibility of studying a competitive economy can be envisioned. If it is even remotely conceivable that such a study can lead to the ability to aggregate the characteristics of an economy, then it becomes possible to conjecture about the more remote study of the characteristics of competitive economies. This sequence possibly, just possibly, outlines a path which will relate this work to a study of the profound issues of our time.

NEW RESEARCH TECHNIQUES IN WORK MEASUREMENT

By WALTON M. HANCOCK

Associate Professor of Industrial Engineering, The University of Michigan

AS A RESULT of our recent research for the Methods-Time Measurement Association, two new techniques have been developed to collect the basic data needed to determine elemental motion times. These methods, which we will call the "Recorder" method and the "Electronic Data Collector" method, were developed primarily to overcome the inherent errors and difficulties in using micromotion pictures for this type of work. The purpose of this paper is to give a brief description of the new techniques and then to compare these techniques with the traditional motion picture method. Other potential uses of the new methods in the work measurement field will also be indicated.

THE RECORDER METHOD

A graphical recorder equipped with carrier amplifiers, such as the one pictured in Figure 1, is used to record the time values as well as the forces occurring within a given operation cycle. Recorders have been used for a long time in other fields of engineering to measure such things as position, velocity, acceleration, and temperature of machine components. However, to my knowledge, they have not been used extensively to measure human motions and the acting forces.

The Recorder, with the proper instrumentation, can give a graphical picture of the

Fig. 1

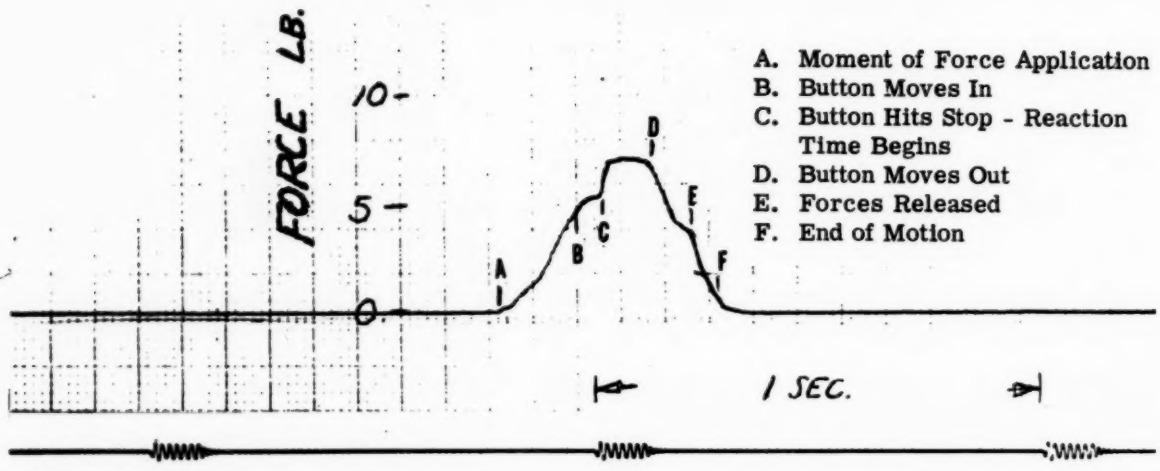

Fig. 2. "Measurement of Forces Occuring During The Activation of a Push Button"

motion of an operator in a work environment. For example, Figure 2 is an actual graph taken on a graphical recorder of an operator pushing a stop button on a machine. Time on the graph is measured horizontally, and force is measured vertically. One can get some idea of the elapsed time for the operation by noting the distance on the chart represented by one second. The particular points of contact and changes in the force in which one is interested are usually determined by noting the places on the graph where sharp changes in the direction of the curve occurs. For example, in Figure 2, points A, B, C, D, E, and F and the elapsed time between them can be determined. The resultant forces occurring in any part of the cycle can also be determined according to the scale on the chart.

In practice, recordings are made of the elements under study, and the points of interest are then read off manually and recorded. Since most of these points are represented by sharp changes in direction of the curves, and since the repeat cycles have the same form, the reduction of the data is a relatively easy, though time consuming task.

In order to use this technique successfully, considerable attention has been paid to the methods of instrumenting the Recorder. We have found the use of pressure sensitive paints, contact switches, microswitches, and particularly small transducers to be successful methods of obtaining the input for the Recorder. Other methods, such as photocells, accelerometers, and potentiometers, can also be used when necessary. By experience, we have been able to find ways of positioning the various input devices on the machines so that they do not interfere with the performance of either the machine or the operator. Since we are using very sensitive equipment, it is also possible to use the body as part of the electrical circuit with success.

We have used the Recorder method in our MTM research for the past two years, and have recently completed a study of the MTM element "Apply Pressure" by use of this method. Much of the data collected were obtained by setting up the Recorder on actual industrial operations in manufacturing concerns in Michigan and Ohio. In the study of elements, such as "Apply Pressure", where the forces applied are a major variable, motion pictures are of little use.

In our research, we have used two of the channels of the Recorder pictured in Figure 1. Since each channel records a particular aspect of the operation, it has been possible to simultaneously record information from two input sources at the same time. There are a number of areas in the work measurement field where we feel that more than two channels will be required. For example, much more information might be necessary if one were to undertake studies of simultaneous motions. The Recorder in the picture, when it is equipped with the proper number of amplifiers, is capable of recording up to eight channels simultaneously.

THE ELECTRONIC DATA COLLECTOR

This method uses the same type of instrumentation as the Recorder. The electrical signals are picked up from the input devices previously discussed; however, the similarity between the methods stops at this point. The electrical signals are fed into the Data Collector, and the elapsed time of each element is punched on paper tape. The points between which time intervals are desired have to be programmed into the Collector. This is accomplished by means of a plug-in logic board.

The Data Collector was designed primarily for the purpose of obtaining information on elemental motions. The machine is pictured in Figure 3. It can measure time intervals over a wide range--from 1/28,000 of a second to twenty-four hours or more. It was intentionally designed to be portable so that it can be taken into an industrial plant and located beside the machine or operation. A power supply of 110 A.C. is required.

Any statistical analysis that is necessary on the data can be performed by feeding the tape directly into a computer equipped for tape input such as the Royal-McBee LGP-30. For computers equipped with card input, the tape can be fed through a tape-to-card converter and the cards used as input to the computer.

The Data Collector system has just recently been completed. Since we have already obtained considerable experience in the application of the various types of input devices that are necessary to set the Collector up on industrial operations, we anticipate that little time will be lost in putting the Collector to use as part of our research efforts.

For an example of the type of information that one is able to obtain on the Collector, please refer to Figure 2. The Collector can be programmed so that the time between the points marked on the graph, denoted as A, B, C, D, E, and F, can be punched on the tape. Since the paper tape can subsequently be put into a computer, no manual reduction of data is required.

We designed the Collector so that it is capable of receiving information in both digital and analog form. The Collector itself is basically a digital device; however, as part of the input circuits to the computer, we have included analog-to-digital conversion components. This enables us to be much more flexible in the types of inputs that can be used and in the type of information that can be obtained.

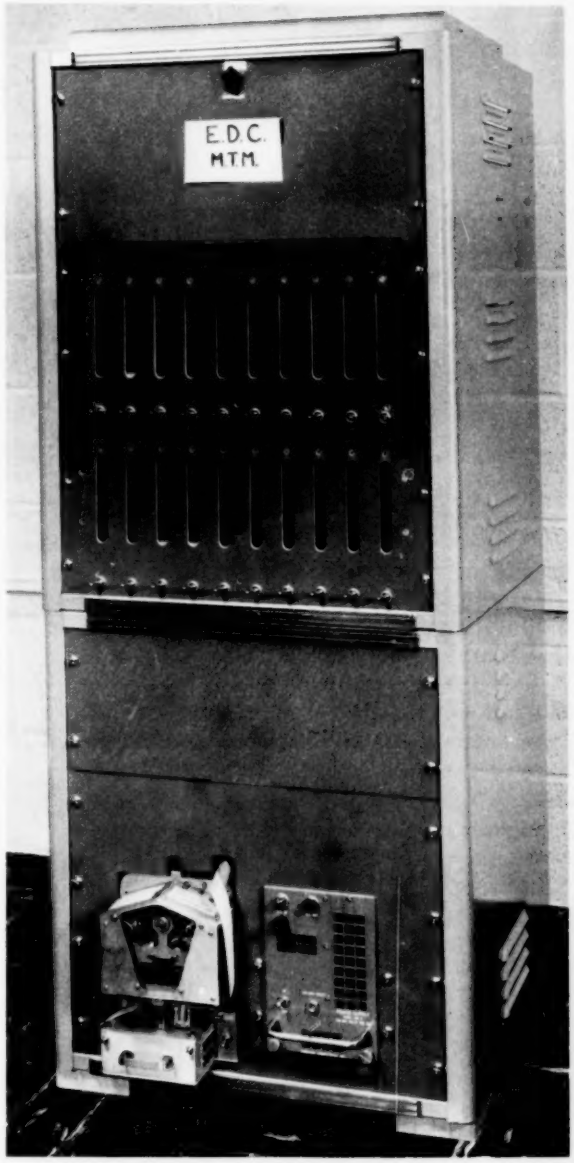

Fig. 3

In order to establish the relative advantages and disadvantages of the Recorder and Data

Collector methods over the traditional micromotion techniques, let us first attempt to specify the desirable characteristics of any research method used to determine elemental time values in the range of 1/28th of a second to 4 seconds. These, in my opinion, would be as follows:

1. The beginning and end points of the element under study should be easy to determine and to define.
2. It should be relatively easy and inexpensive to obtain representative sample sizes, not only in the laboratory but also in actual production operations.
3. The method of data recording should be capable of measuring information in very small intervals of time as compared to the total time of the element under study.
4. The data recording equipment should not have any constant error (bias).
5. The recording method should have as little effect as possible on the operator while the data is being recorded.
6. The process of reducing the data should be as free of error as possible.
7. The set-up of equipment should be fast and relatively easy.
8. As many as possible of the variables that effect the element under study should be capable of measurement.
9. The equipment should be of reasonable cost.

The following table is an attempt to compare the three methods according to the criteria just listed.

RELATIVE MERITS OF THE DIFFERENT METHODS

Evaluation Criteria	Micromotion Techniques	Graphical Recorder	Electronic Data Collector
Determination of Beginning and End Points	Difficult - Occurs frequently between frames.	Easy - Usually determined by sharp changes in curves.	Easy - Points are programmed into computer.
Ease of Obtaining Representative Sample Sizes	Difficult - Usually requires large amounts of film.	Fairly Difficult - Usually requires large amounts of graph paper.	Easy - Data is reduced and punched on paper tape.
Accuracy of Recording Technique	Poor - Average error is a frame which is 1/64 sec. or more (1/2 frame at beginning plus 1/2 frame at end).	Good - Error due to response time of equipment: 1/1000 sec. or less.	Excellent - Dependent upon Oscillator design - 1/28,000 sec. or less.
Equipment Error (Bias)	Excellent - If synchronous motor camera is used, error is predictable, but negligible.	Excellent - No error.	Excellent - Negligible error in well designed system.
Effect on Operator	Poor - Picture taking affects operator performance. Accommodation not usually possible.	Good - Wires, transducers can be positioned. Operator has time to accommodate before data is taken.	Good - Same comments as Recorder except computer is capable of operating continuously over long periods without attention.

RELATIVE MERITS OF THE DIFFERENT METHODS (Concl'd)

Evaluation Criteria	Micromotion Techniques	Graphical Recorder	Electronic Data Collector
Data Reduction Errors	Poor - Hard to read large amounts without errors. Error checking very difficult.	Good - Data obtained from continuous graphs. Easy to recheck for errors.	Excellent - Only possible sources are where operator interrupts cycle, or performs elements out of sequence.
Set Up	Easy - Use of cameras is well known.	Harder - Ingenuity is required to locate transducers and contact switches	Harder - Same as Recorder.
Variables That Can Be Measured	Limited - Time and distance can be measured.	Less Limited - Time, forces, acceleration and in certain cases position can be determined. Simultaneous motions can be determined.	Less Limited - Time, forces, acceleration and position in space can be determined with the help of a computer.
Cost	$300-$2400 depending on lenses and camera.	$4000-$8000 depending on the number of amplifiers.	$8000-$10,000 (to reproduce Collector).

This table in one sense represents an incomplete picture because it gives the impression that one technique has to be chosen, and all of the work done with it. Actually, the use of all three techniques helps to obtain the best understanding. Motion pictures are used to provide historical records of the operation under observation; the Recorder method is used as an aid in setting up the instrumentation for the Data Collector, and the Collector is used to collect and reduce the data for final analysis.

One of the most important advantages of the use of the Data Collector in this type of research is the relative ease and speed with which one can obtain large amounts of information on a particular element. This characteristic will enable us to use much more sophisticated statistical techniques in our analysis. We have determined, that the man-hours to do research, at least in one particular instance, could have been reduced from approximately 5-man-months to less than 1-man-month if we had had the Data Collector available. In addition, we would have had much more information, and the data would have been in a more complete and accurate form.

OTHER POTENTIAL USES OF THE NEW METHODS

As mentioned previously, the Electronic Data Collector is portable and is capable of operating from any 110 volt A.C. line for long periods of time. In addition, the Collector can be reduced to the size of a large suitcase by using transistors in its construction. This would increase the portability of the Collector and also make it less susceptible to damage. Although we have primarily developed the Collector for use in the determination of elemental times, we feel that the following related work measurement areas will also benefit by its application.

1. Fatigue studies. The Collector is capable of recording cycle times either

continuously or at a specified sampling rate over long periods of time; therefore, it could be used to measure the trends in the length of cycle time.

2. Machine interference studies. The Collector can be programmed so that it would record the times when two or more machines are idle at the same time. In the situation where one operator is operating more than one machine, the Collector could serve as a tool for determining the proper allowances to be applied to standards for the interference time.
3. More consistent rating methods. As we all know, rating is one of the biggest sources of error in the work measurement system. With a collection instrument such as this, it would be possible to collect large numbers of elements and compare the ratings given for a cycle with the variation in the elemental times within the cycle. In this way, one should be able to correlate those elements which most significantly affect the rating given by the analyst. Once this is determined, the concept of normal time could be related to the length of certain elements within the cycle.
4. The effects of learning on cycle times. The comments under fatigue studies, above, also apply here. Since the Collector can record cycle times over indefinite periods of time, one has a method of measuring the change in performance of operators while they are learning.

A number of the above items are of interest not only to those whose main interest is work measurement research but also to the practicing industrial engineer. Several industrial firms are considering duplicating the Data Collector because of its ability to record information directly from a production operation.

The Recorder method can also be used in all instances listed above, but in comparison with the Collector method, it has two drawbacks: the data has to be reduced manually, and the recorder must be attended during its entire operating time. This method, therefore, is of primary value in the initial stages of work where continuous descriptive information is needed. As previously mentioned, the area in which the Recorder method will be used most extensively is in work on simultaneous motions of body members where the multiple channels can be used to measure motions that are occurring simultaneously.

Senior Chapters

1. Columbus, Ohio
2. Dayton, Ohio
3. Pittsburgh, Pennsylvania
4. Jamshedpur, India
5. Metropolitan New York
6. Atlanta, Georgia
7. Cleveland, Ohio
8. Cincinnati, Ohio
9. Birmingham, Alabama
10. Dallas-Ft. Worth, Texas
11. East Tennessee
12. San Francisco-Oakland, Calif.
13. Syracuse, New York
14. Washington, D. C.
15. Tulsa, Oklahoma
16. St. Louis, Missouri
17. Tri-Cities, Tennessee
18. Louisville, Kentucky
19. Stark County, Ohio
20. Seattle, Washington
21. Winston-Salem, North Carolina
22. Houston, Texas
23. Los Angeles, California
24. Youngstown, Ohio
25. Chicago, Illinois
26. Savannah, Georgia
27. Jacksonville, Florida
28. Memphis, Tennessee
29. San Diego, California
30. Boston, Massachusetts
31. Philadelphia, Pennsylvania
32. Rocky Mountain, Colorado
33. Pensacola, Florida
34. Fort Wayne, Indiana
35. Central Indiana
36. Toledo, Ohio
37. Peninsula, California
38. Twin City, Minn. & Wis.
39. San Antonio, Texas
40. Miami, Florida
41. Baton Rouge, Louisiana
42. Baltimore, Maryland
43. Sacramento, California
44. Rochester, New York
45. Milwaukee, Wisconsin
46. Mississippi Valley, Ia. & Ill.
47. Detroit, Michigan
48. Southern Tier, New York
49. Niagara Frontier, New York
50. Great Salt Lake, Utah
51. Erie, Pennsylvania
52. Akron, Ohio
53. Calumet, Indiana
54. Chattanooga, Tennessee
55. Macon, Georgia
56. Wichita, Kansas
57. Oklahoma City, Oklahoma
58. Charleston-Huntington, W. Va.
59. Albuquerque Area, N. M.
60. East Texas
61. Metropolitan New Jersey
62. Merrimack Valley, N. H. & Mass.
63. Tri-State, New Hampshire
64. Middle Tennessee
65. Indianapolis, Indiana
66. Eastern North Carolina
67. Portland, Oregon
68. Worcester, Massachusetts
69. North Alabama
70. Central Arizona
71. Lancaster Area, Pennsylvania
72. York, Pennsylvania
73. Nashville, Tennessee
74. New Orleans, Louisiana
75. Central Connecticut
76. Mid-Hudson, New York
77. Lehigh Valley, Pennsylvania
78. San Gabriel Valley, California
79. Mobile, Alabama
80. Central Illinois
81. Western Virginia
82. Southwestern Connecticut
83. Western North Carolina
84. Central Arkansas
85. Mohawk Valley, New York
86. Long Island, New York
87. Southern Ontario, Canada
88. Evansville, Indiana
89. Susquehanna Valley, Penn.
90. Omaha, Nebraska
91. Florida West Coast
92. Kansas City
93. Northwest Georgia
94. Springfield, Massachusetts

95. Harrisburg Area, Pennsylvania
96. Binghamton, New York
97. Naugatuck Valley, Connecticut
98. Saginaw Valley, Michigan
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106. Montreal, Canada
107. New York, Pennsylvania
108. Hawaii
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Wayne State University
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